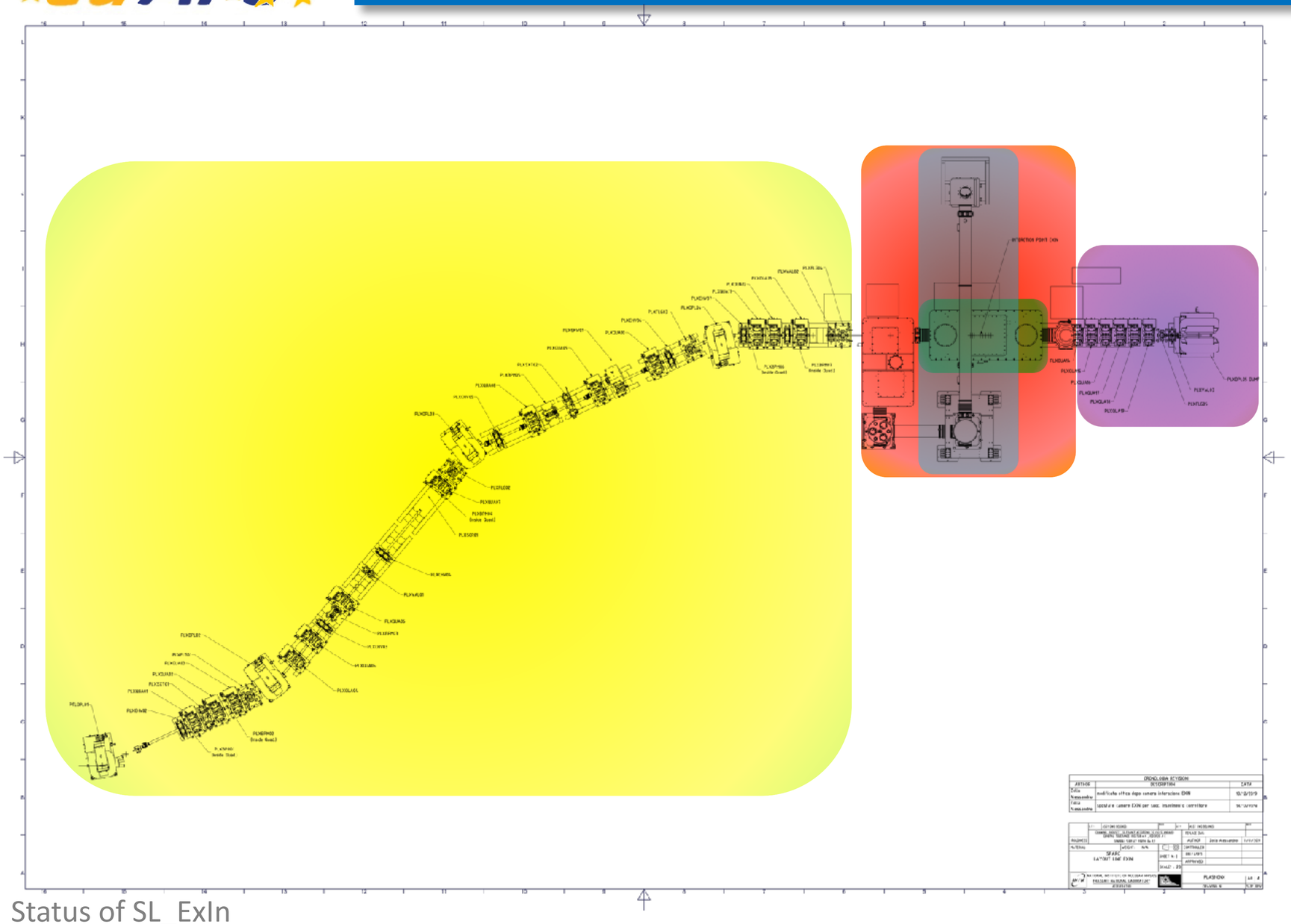
Status of SL_ExIn

A.R. Rossi

on behalf of the SL_ExIn team

INSTALLATIONS STATUS

ExIn line layout



Electrons transport and matching line

Interaction area

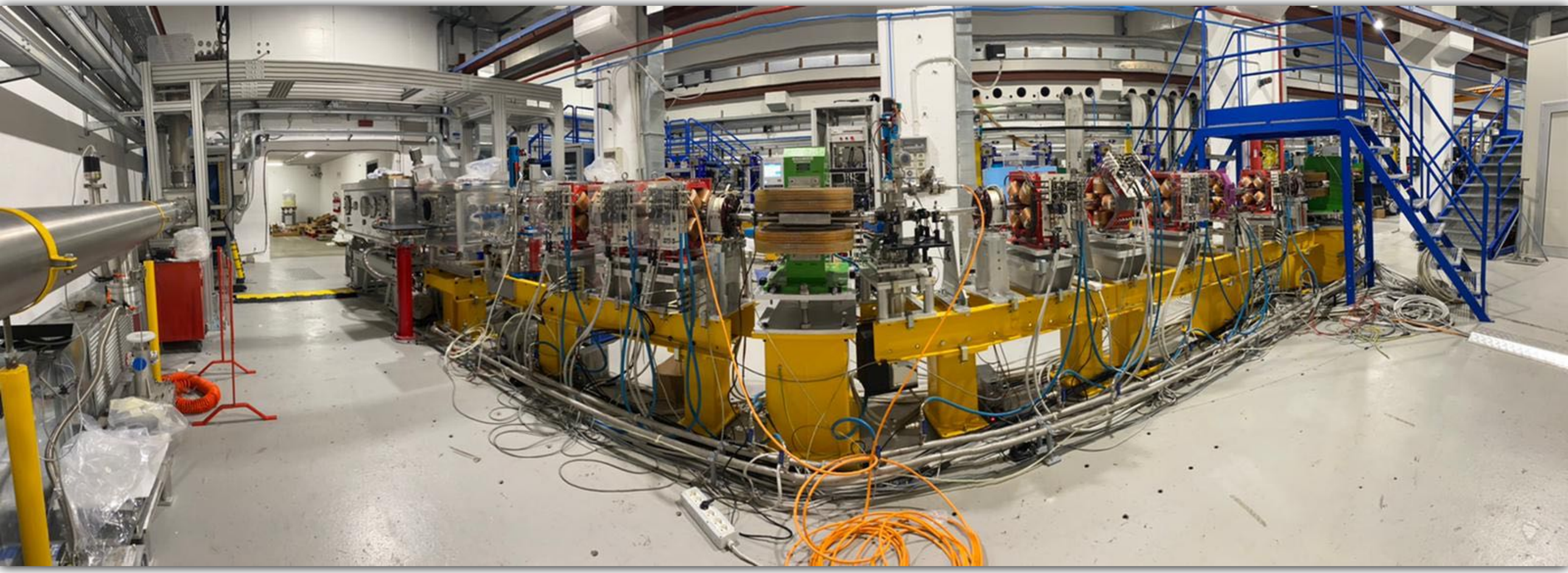
- Interaction chamber

Laser transport

Electrons dump line

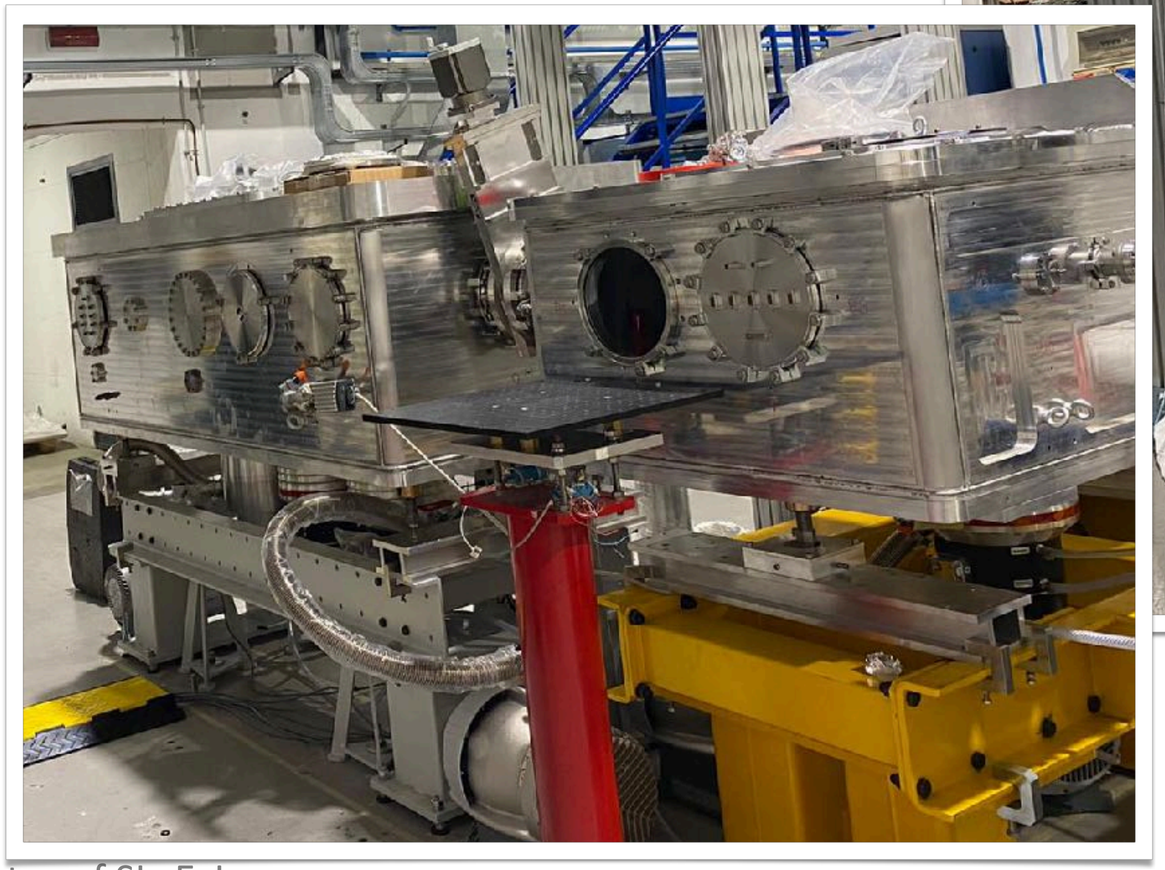
Electron transport and matching line

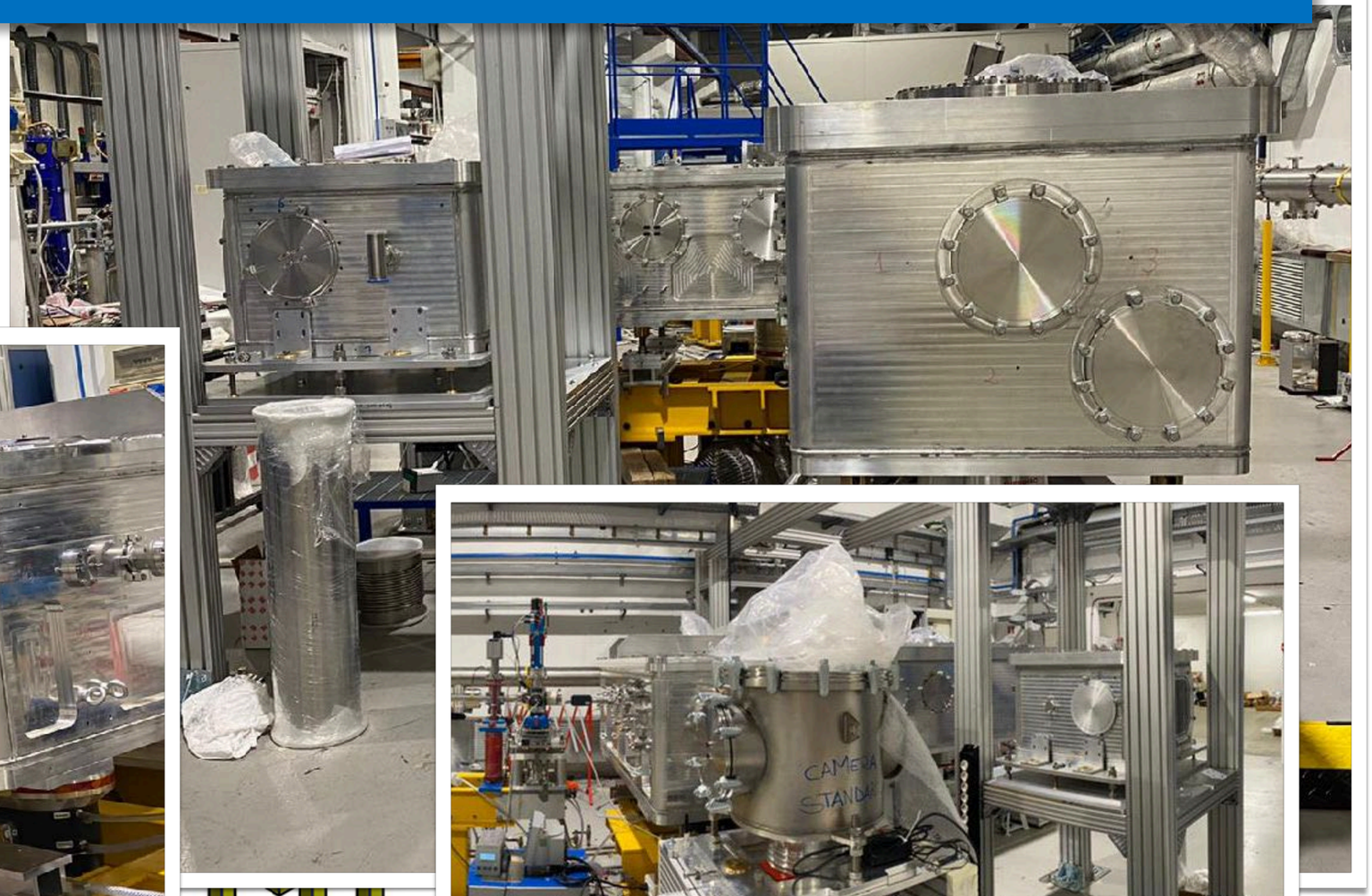
- 98% installed.
- A few fine tuning may be needed.
- Vacuum tested.



Interaction area

- 80% installed.
- Vacuum tested.
- Final alignment needed.

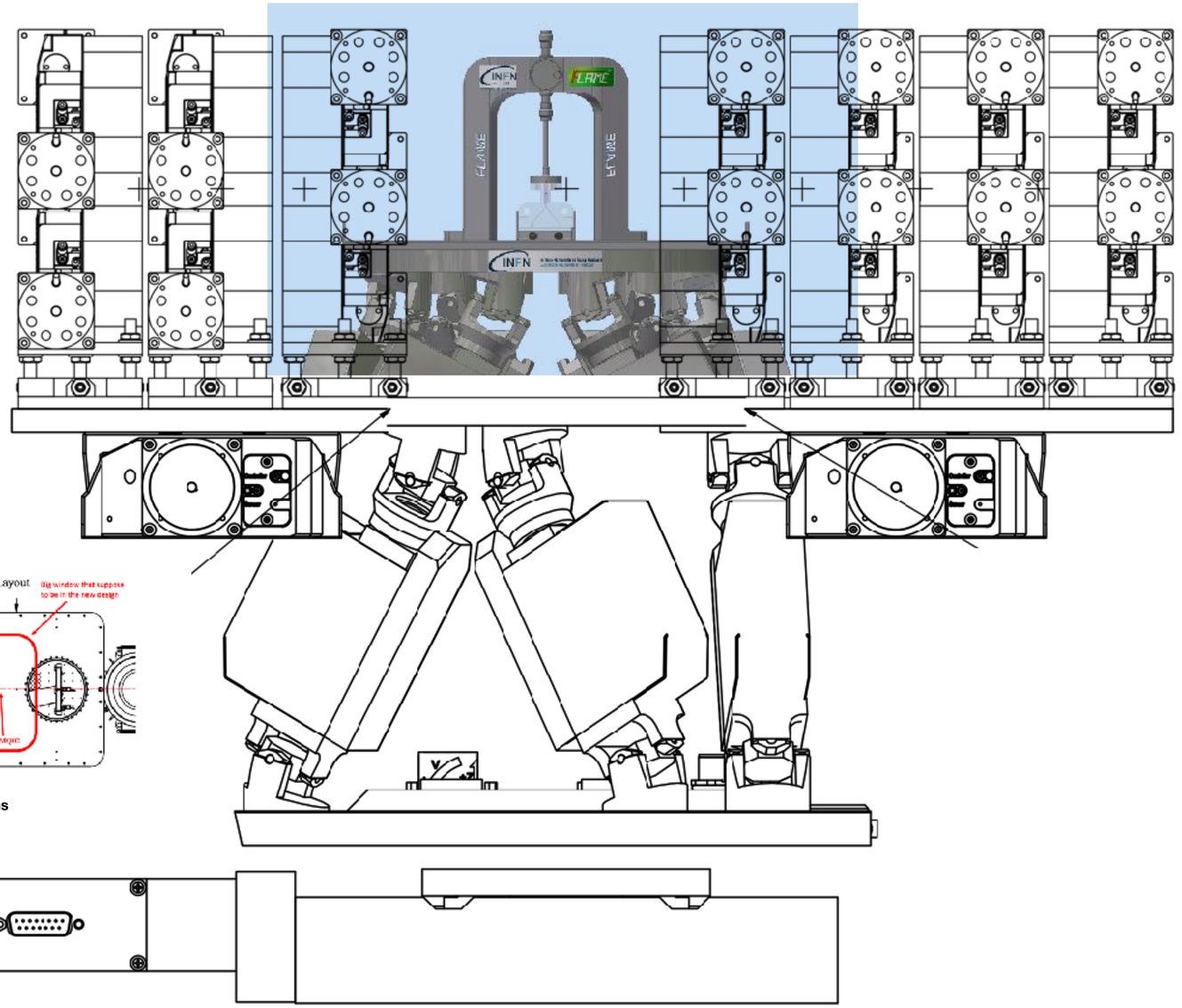


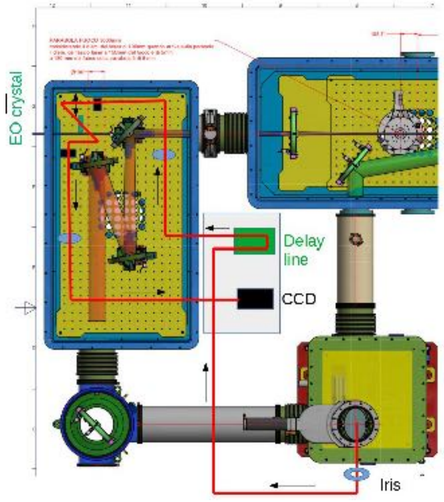


Interaction chamber

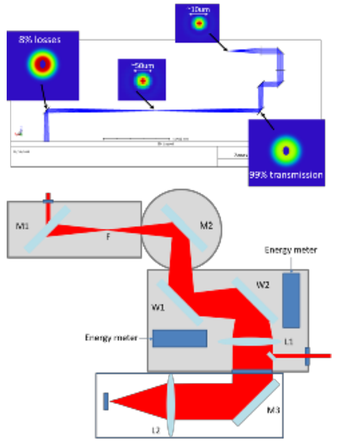
What goes inside:

- Diagnostics
- Exapod
- Plasma target
- Variable permanent magnet quads (CPMQ)

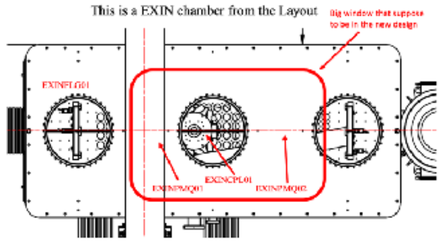




EOS



Laser post-interaction



Flags for electrons

Interaction chamber: ISSUE (1)

The design of VPMQ is not complete.

Integration of IC components and IC final design cannot proceed until VPMQ is completed.

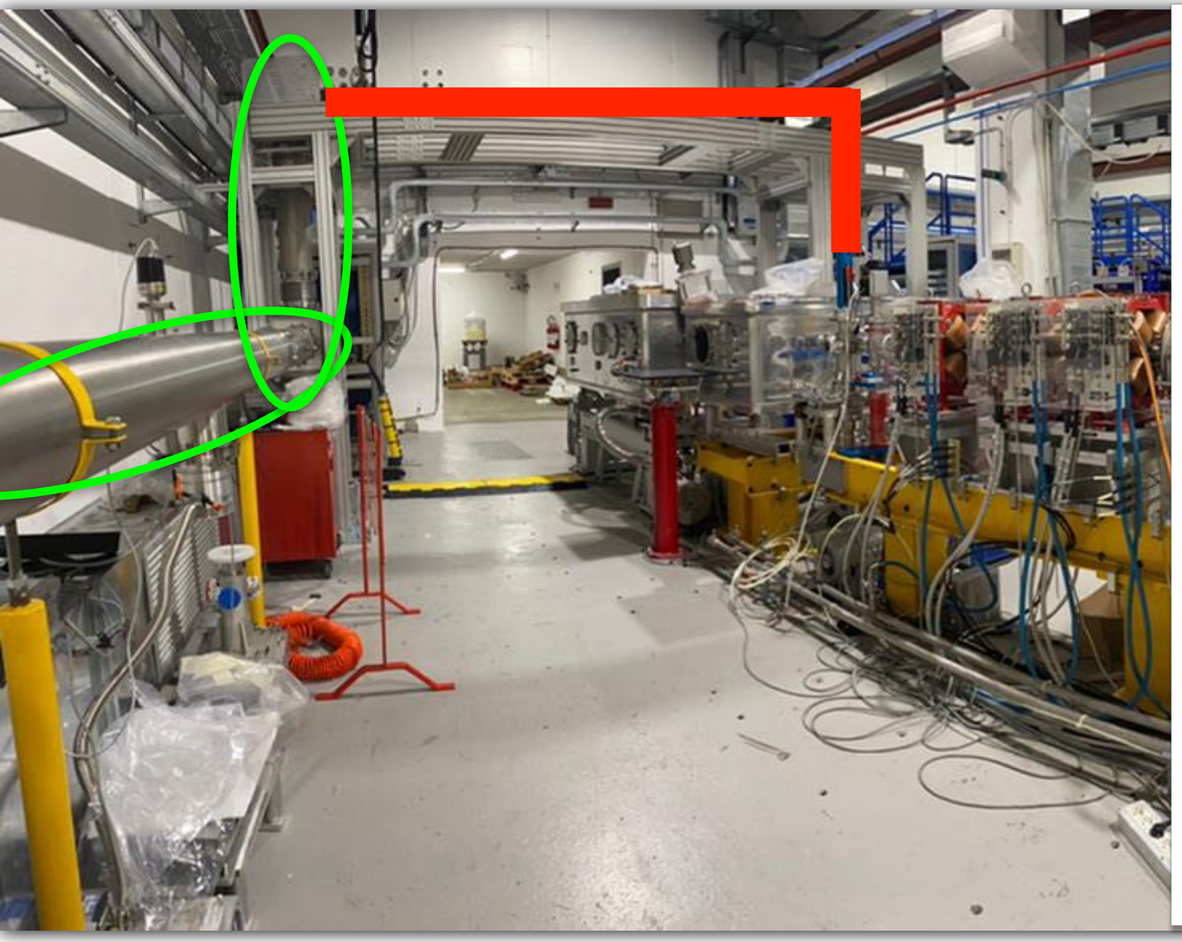
Procurement of VPMQ may take a long time, depending also on actual geopolitical situation.

However, this are not necessarily bad news for EuAPS!

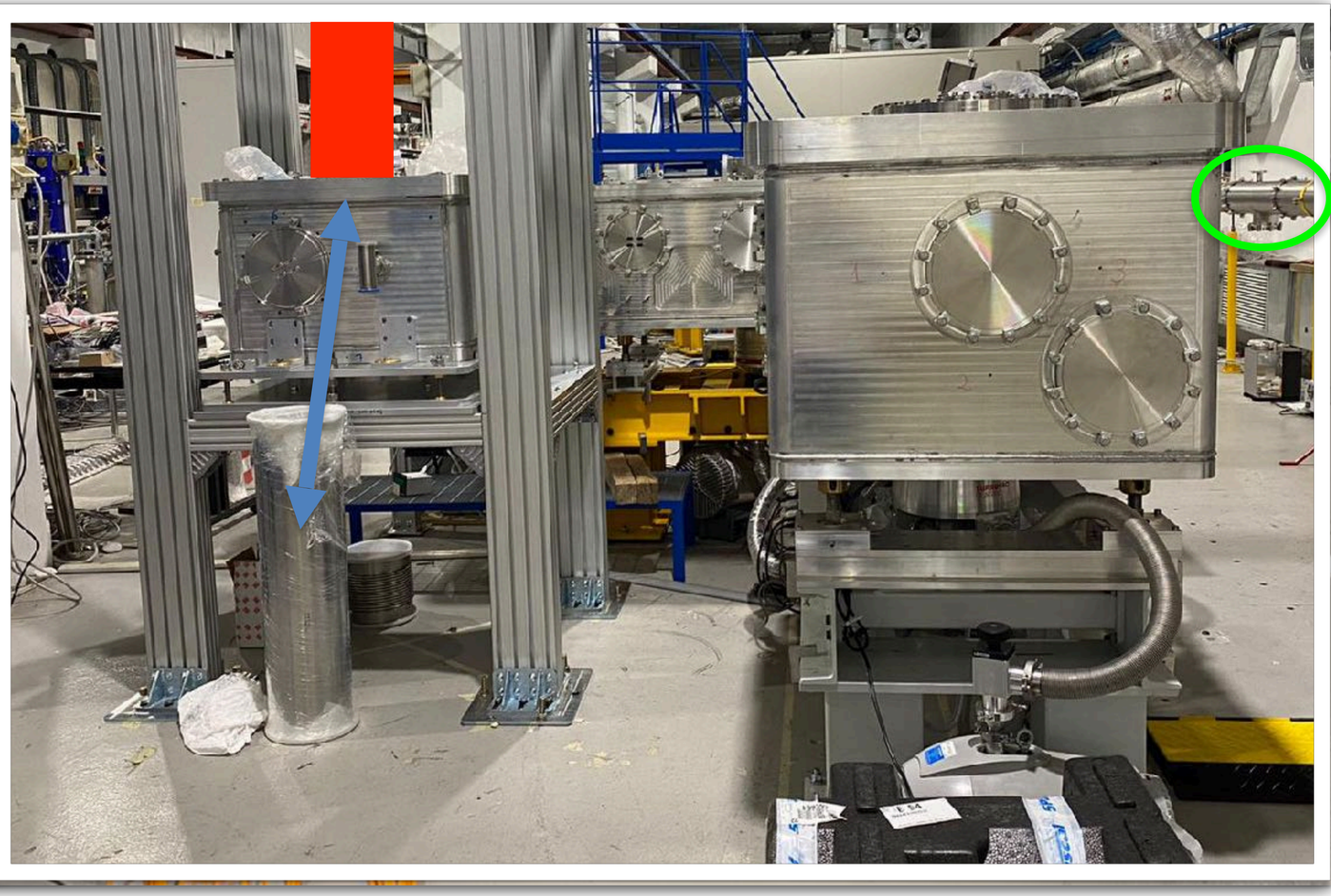
In the meanwhile we are working for preparing synchronization tests that do not require VPMQ

Laser transport

INSTALLED



RECENTLY INSTALLED/ TO BE INSTALLED

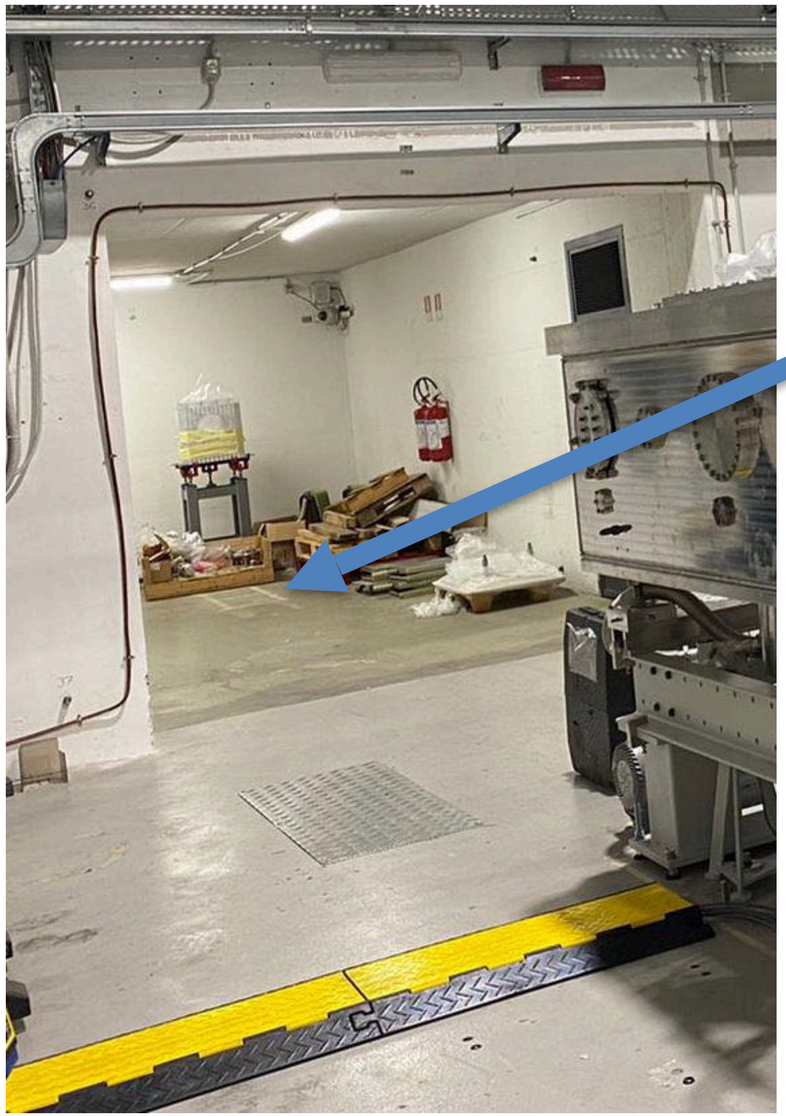


Laser transport: ISSUE (2)

The laser final focusing returns a laser spot smaller than the one foreseen by the optimal working point.

- That spot would be optimal for operation at $n_0 = 10^{18}$ cm^{-3}
- The required electron beam cannot be delivered by SPARC
- We investigated two alternatives:
    1. Keep current spot and tune n_0
    2. Keep nominal $n_0 = 10^{17}$ cm^{-3} and avoid guiding (or allow mismatched guiding)
- Both alternatives give very poor results in term of beam parameters

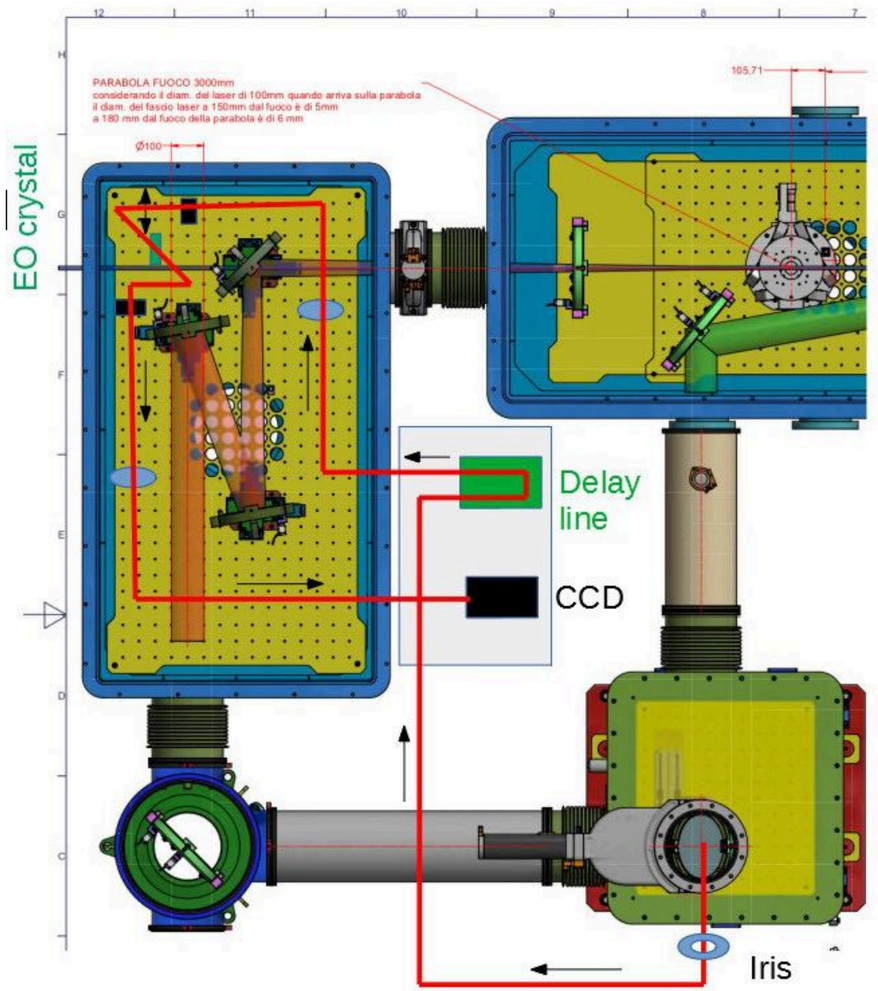
Electrons dump line



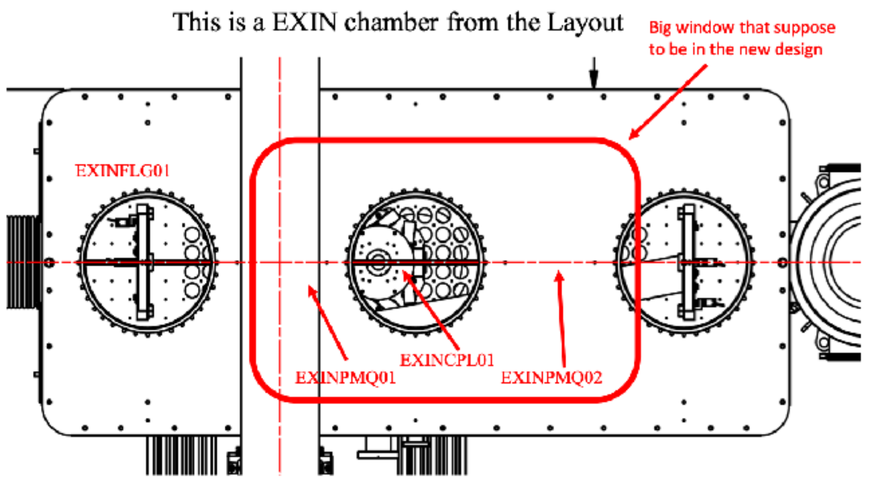
Dumping line is NOT there!
However:

- Line has already been designed
- The dump hole has already been carved and refined
- Electron optics already owned (quads and dump dipole)
- Optics supports are in design phase or ready for production
- Dump’s Pb has been recovered from PLASMONX line
- Only vacuum chambers (pipes) are missing

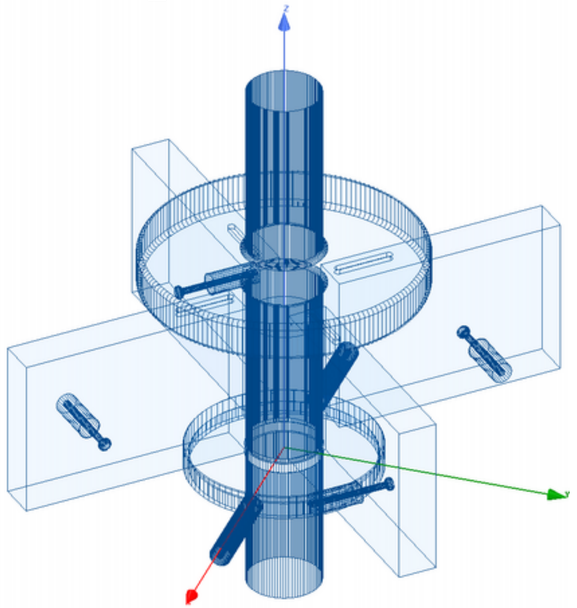
Diagnostics



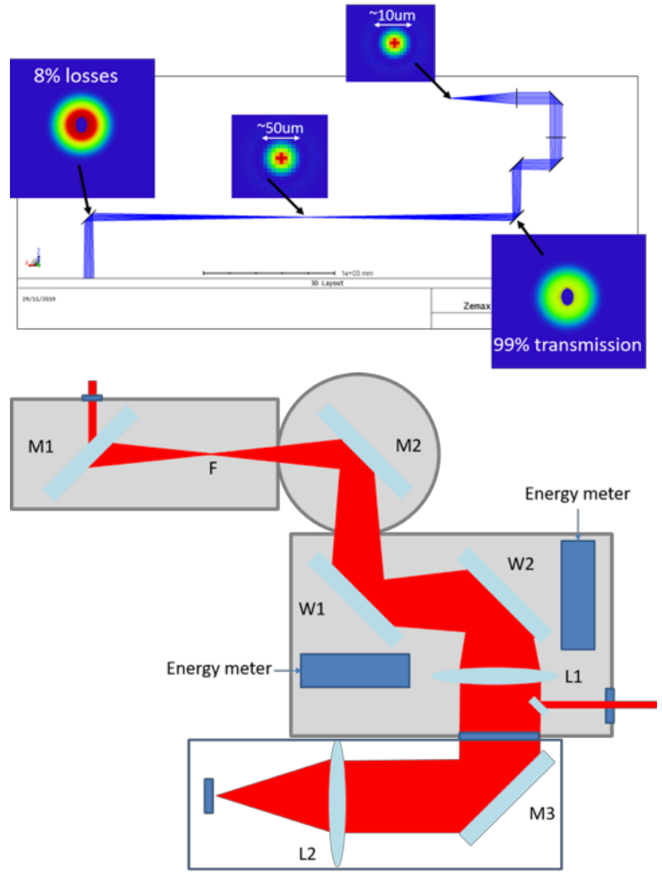
EOS



Flags for electrons



BPMs and CBPMs

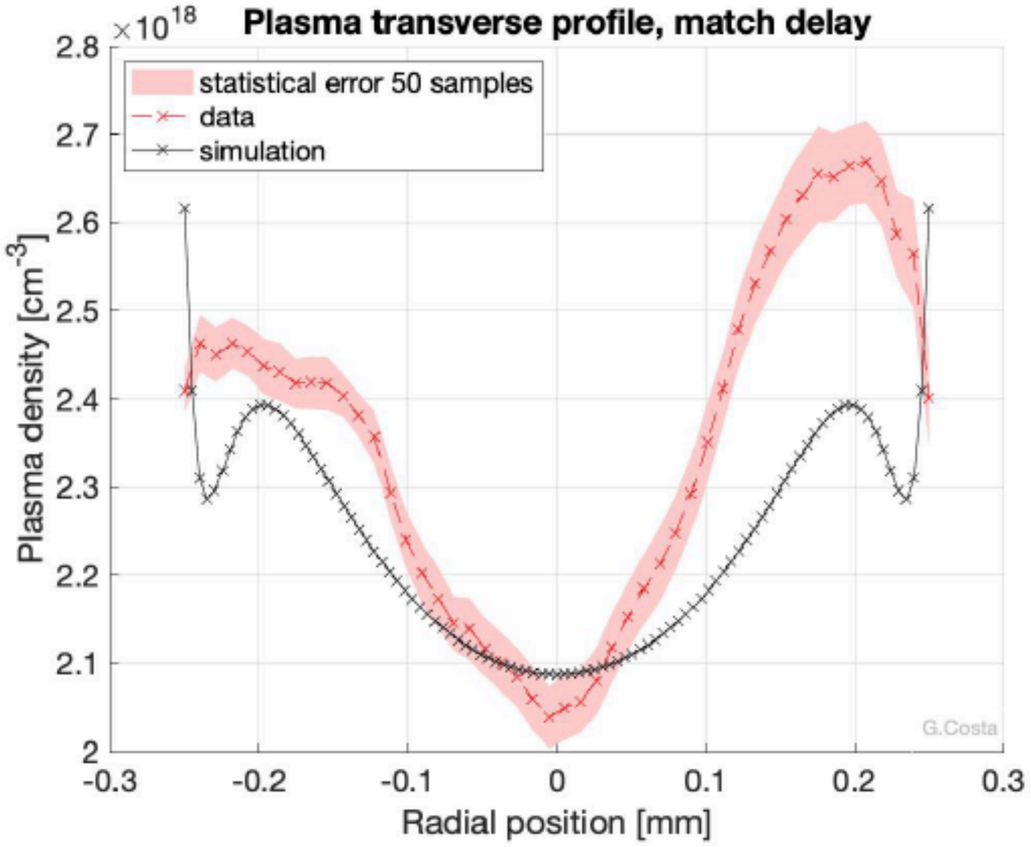


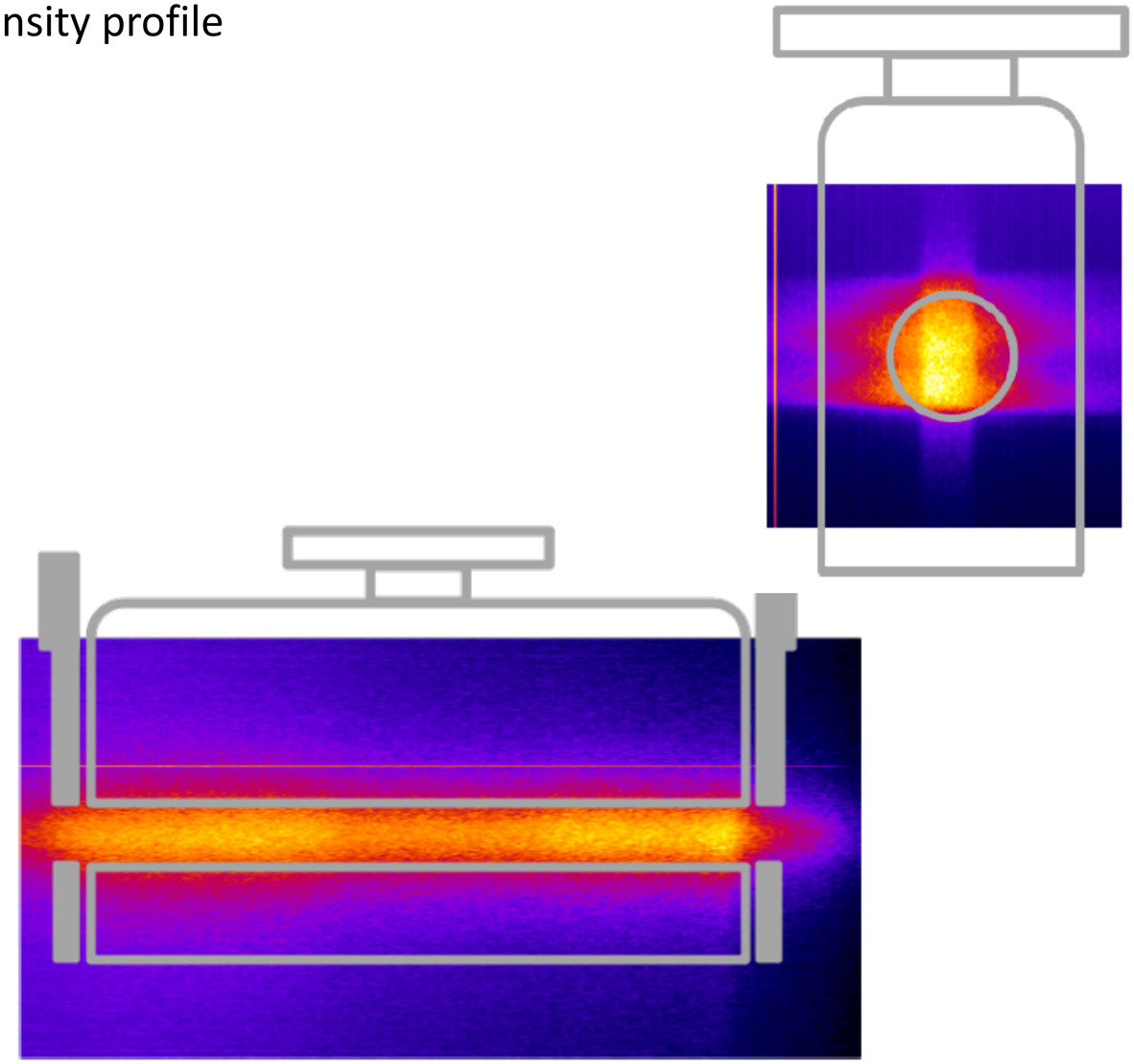
Laser post-interaction

EXPERIMENTAL TESTS STATUS

Plasma density characterization

Laser guiding requires a transverse plasma parabolic density profile





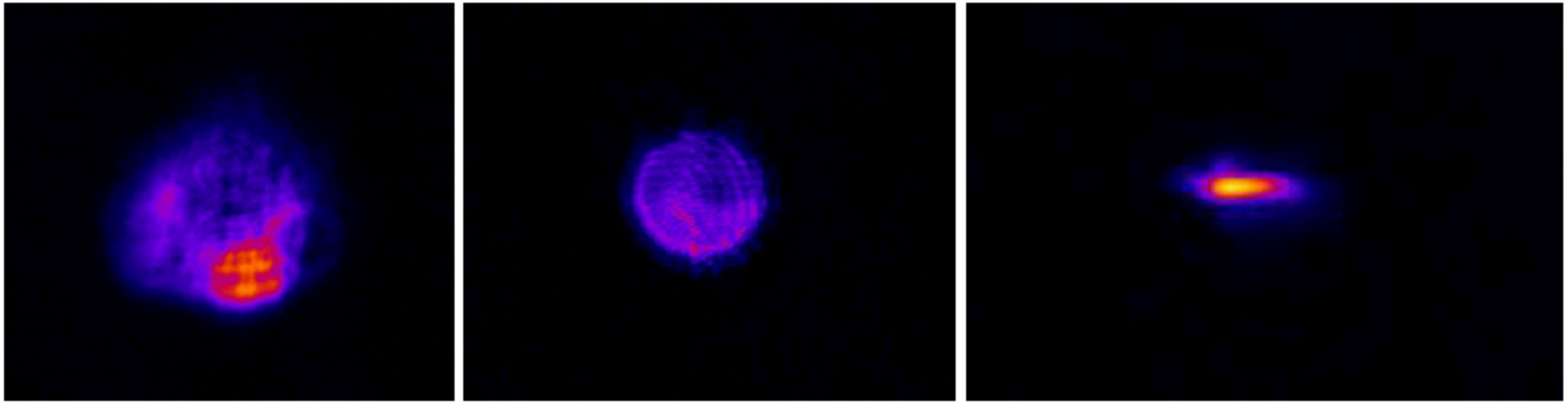
Plasma density: ISSUE (3)

The combination of capillary radius and plasma nominal density do not return the correct transverse profile to guide laser at the nominal radius value, unless capillary radius is rather small (< 100 µm)

Capillary radius [um]	100	100	100	100	100	100	100	100	100	100
Plasma density [cm-3]	1E+17	2E+17	3E+17	4E+17	5E+17	6E+17	7E+17	8E+17	9E+17	1E+18
Matching radius 1/e2 [um]	83.5791	70.2814	63.5064	59.0994	55.8927	53.4023	51.3835	49.6964	48.2544	47
a0	0.6045	0.7189	0.7956	0.8549	0.904	0.9462	0.9833	1.0167	1.0471	1.075
Capillary radius [um]	150	150	150	150	150	150	150	150	150	150
Plasma density [cm-3]	1E+17	2E+17	3E+17	4E+17	5E+17	6E+17	7E+17	8E+17	9E+17	1E+18
Matching radius 1/e2 [um]	102.3631	86.0768	77.7791	72.3817	68.4543	65.4042	62.9316	60.8655	59.0994	57.563
a0	0.4936	0.587	0.6496	0.6981	0.7381	0.7725	0.8029	0.8301	0.8549	0.8778
Capillary radius [um]	200	200	200	200	200	200	200	200	200	200
Plasma density [cm-3]	1E+17	2E+17	3E+17	4E+17	5E+17	6E+17	7E+17	8E+17	9E+17	1E+18
Matching radius 1/e2 [um]	118.1987	99.3929	89.8116	83.5791	79.0443	75.5223	72.6672	70.2814	68.2421	66.468
a0	0.4275	0.5084	0.5626	0.6045	0.6392	0.669	0.6953	0.7189	0.7404	0.7602
Capillary radius [um]	250	250	250	250	250	250	250	250	250	250
Plasma density [cm-3]	1E+17	2E+17	3E+17	4E+17	5E+17	6E+17	7E+17	8E+17	9E+17	1E+18
Matching radius 1/e2 [um]	132.1502	111.1246	100.4124	93.4443	88.3742	84.4365	81.2444	78.577	76.297	74.3135
a0	0.3823	0.4547	0.5032	0.5407	0.5717	0.5984	0.6219	0.643	0.6622	0.6799

Laser guiding tests

Laser pulse at capillary exit



a) w/o capillary

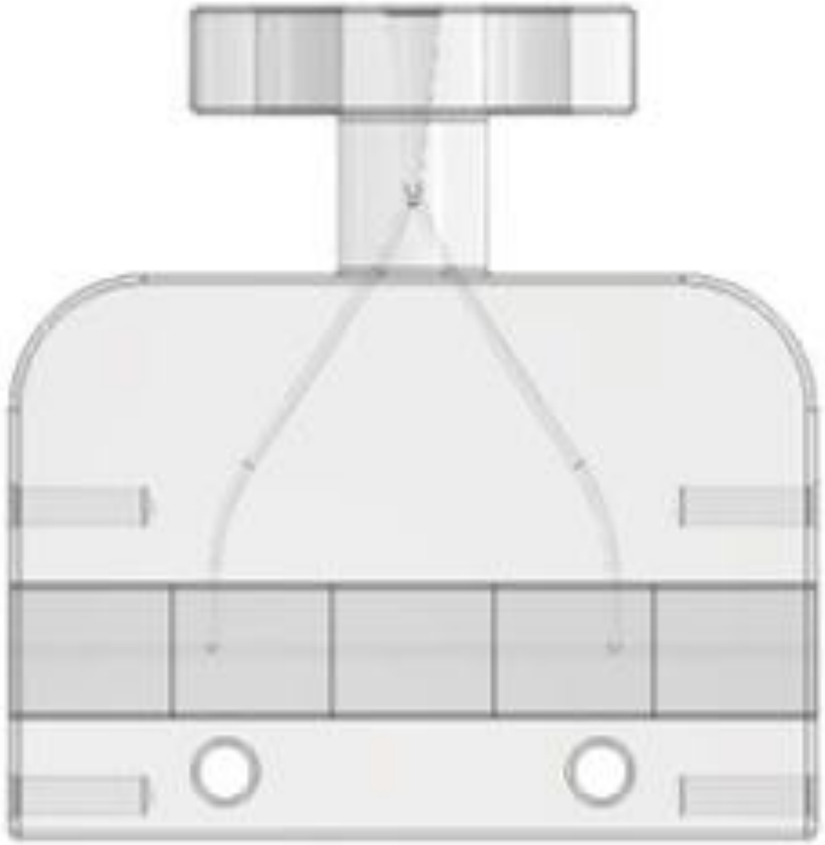
b) with capillary w/o guiding

c) with capillary & guiding

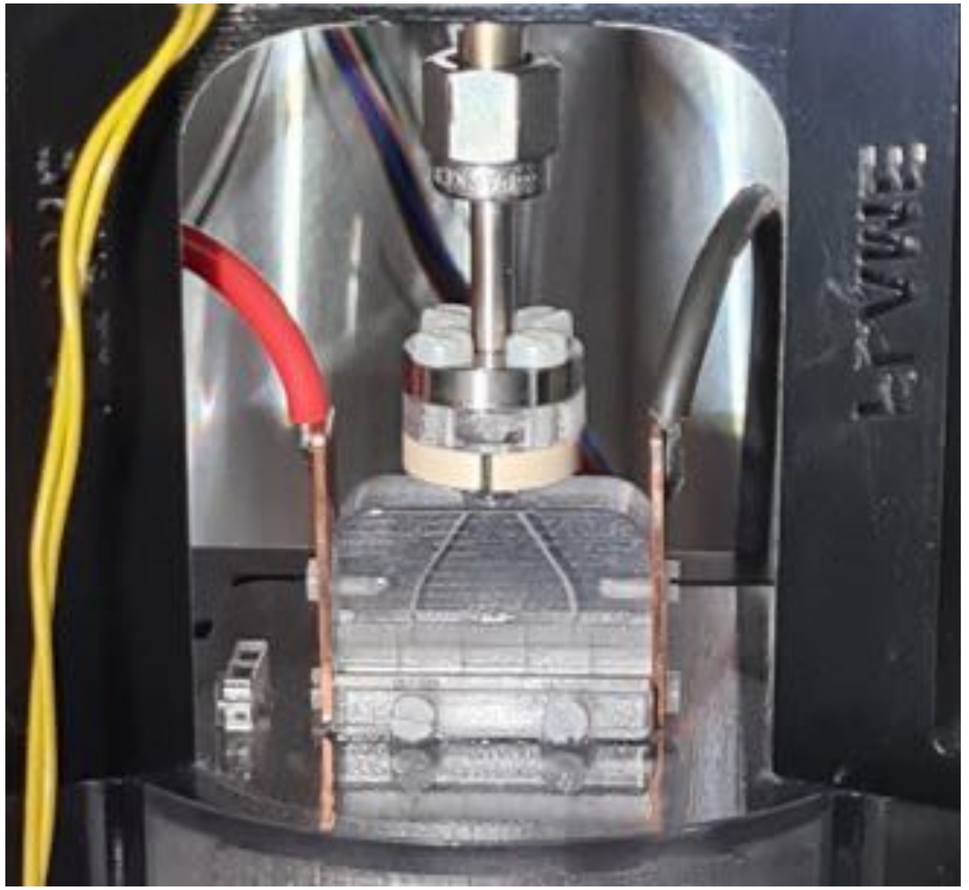
High power guiding tests to be performed with Sa capillary

Sa segmented capillary

To overcome the damage problems to plastic capillaries, an assembled sapphire capillary has been designed and tested.

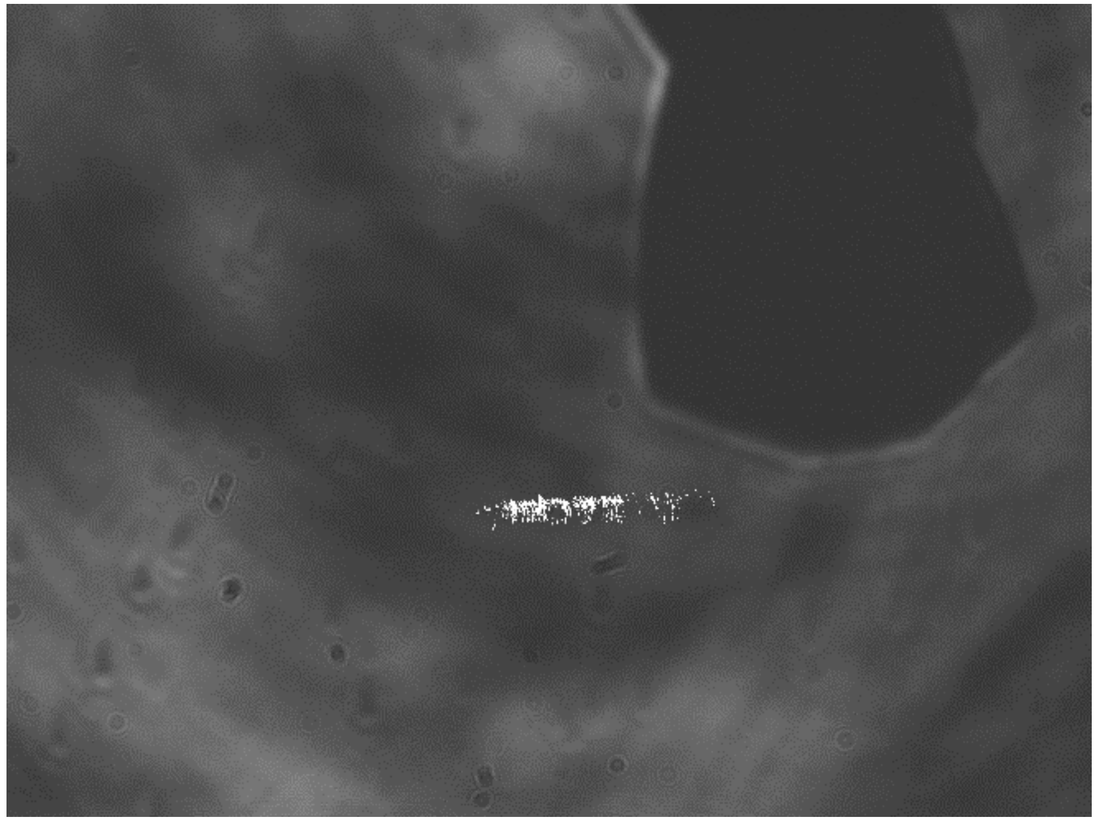


Plastic, 3D printed, capillaries holder

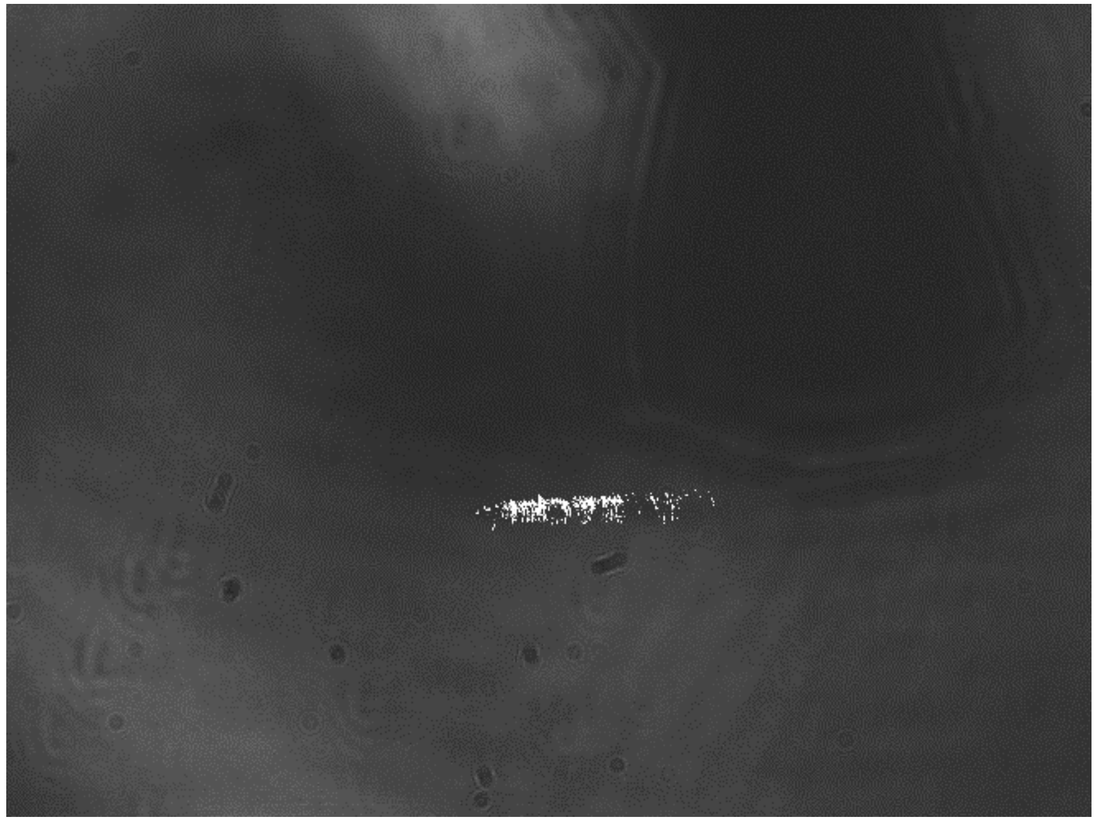


Laser removal

w/o capillary



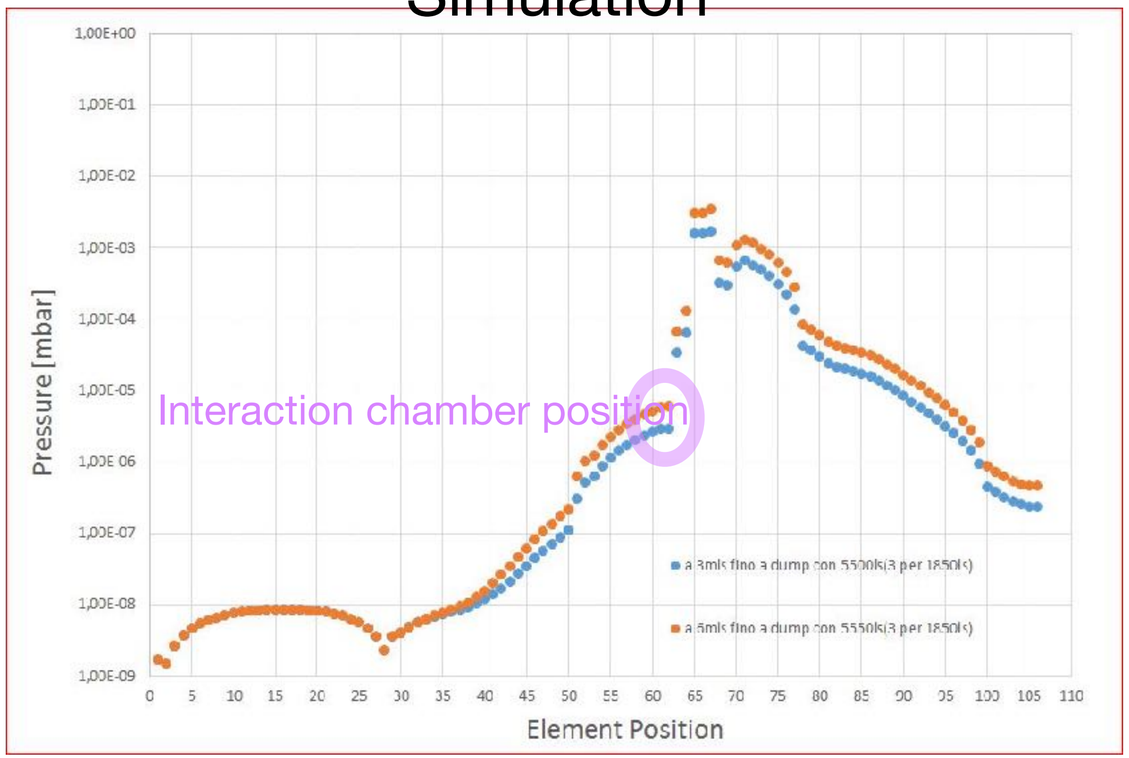
With capillary



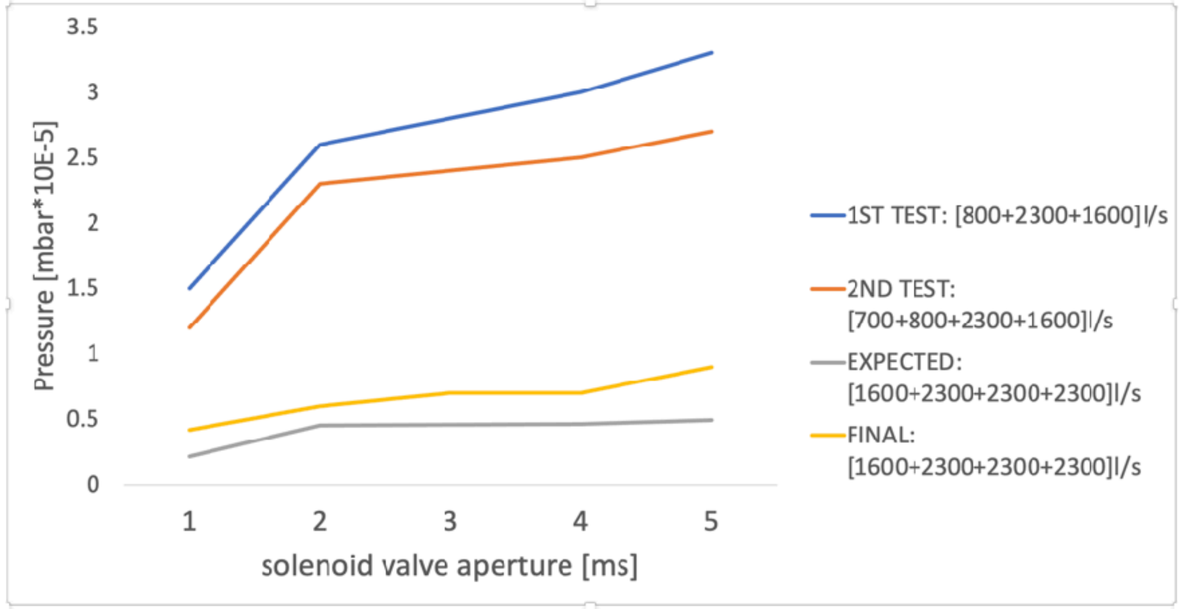
The high power laser pulse needs to be removed after interaction for avoiding damages and blinding diagnostics. Most of the pulse is deflected by a mirror with a hole. This test represents a way to remove also the portion passing through the hole.

IC vacuum simulations and measurements

Simulation



Measurements

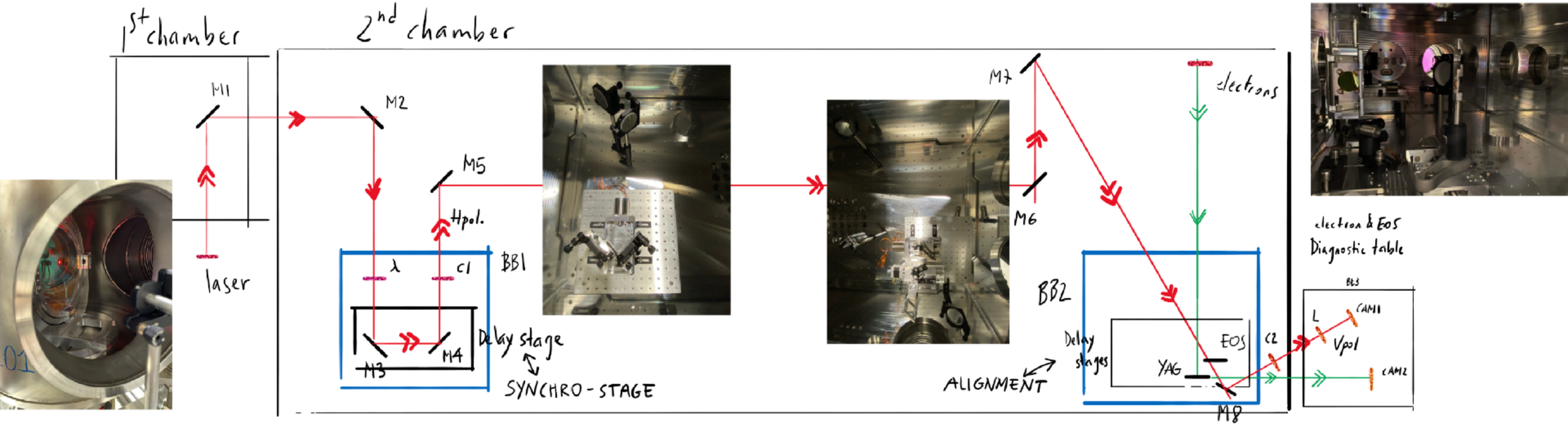


The expected (extrapolated using 1st and 2nd tests) value was used for dimensioning the final pumping system

Plasma is generated from hydrogen, but RF structures require UHV. Correctly dimensioning the vacuum pumping system is paramount for operating with plasma and avoid damages to the accelerator.

Next step: synchronization measurements

Electrons - laser arrival time jitters



M.- mirrors
λ- polarization control stage
c- polarizing cubes
L- imaging lens

External injection is very demanding in synchronization: $\Delta t \lesssim 20$fs

SIMULATIONS STATUS

Working point definition

Dates back to 2012:

Proceedings of IPAC2012, New Orleans, Louisiana, USA WEEPPB002

PLASMA ACCELERATION EXPERIMENT AT SPARC_LAB WITH EXTERNAL INJECTION

A.R. Rossi*, M. Belleveglia, M. Castellano, E. Chiadroni, G. Di Pirro, A. Gallo, M. Ferrario,
G. Gatti, C. Vaccarezza, INFN/LNF, Frascati, Italy
A. Bacci, L. Serafini, INFN/MI, Milan, Italy
A. Cianchi, Università di Tor Vergata, Rome, Italy
C. Maroli, V. Petrillo, P. Tomassini, Università di Milano, Milan, Italy
A. Mostacci, Univarsità di Roma "La Sapienza", Rome, Italy

Refined in 2014:

ELSEVIER CrossMark Available online at www.sciencedirect.com ScienceDirect Physics Procedia 52 (2014) 90 – 99 Physics Procedia

Physics and Applications of High Brightness Beams Workshop, HBEB 2013

External-Injection experiment at SPARC_LAB

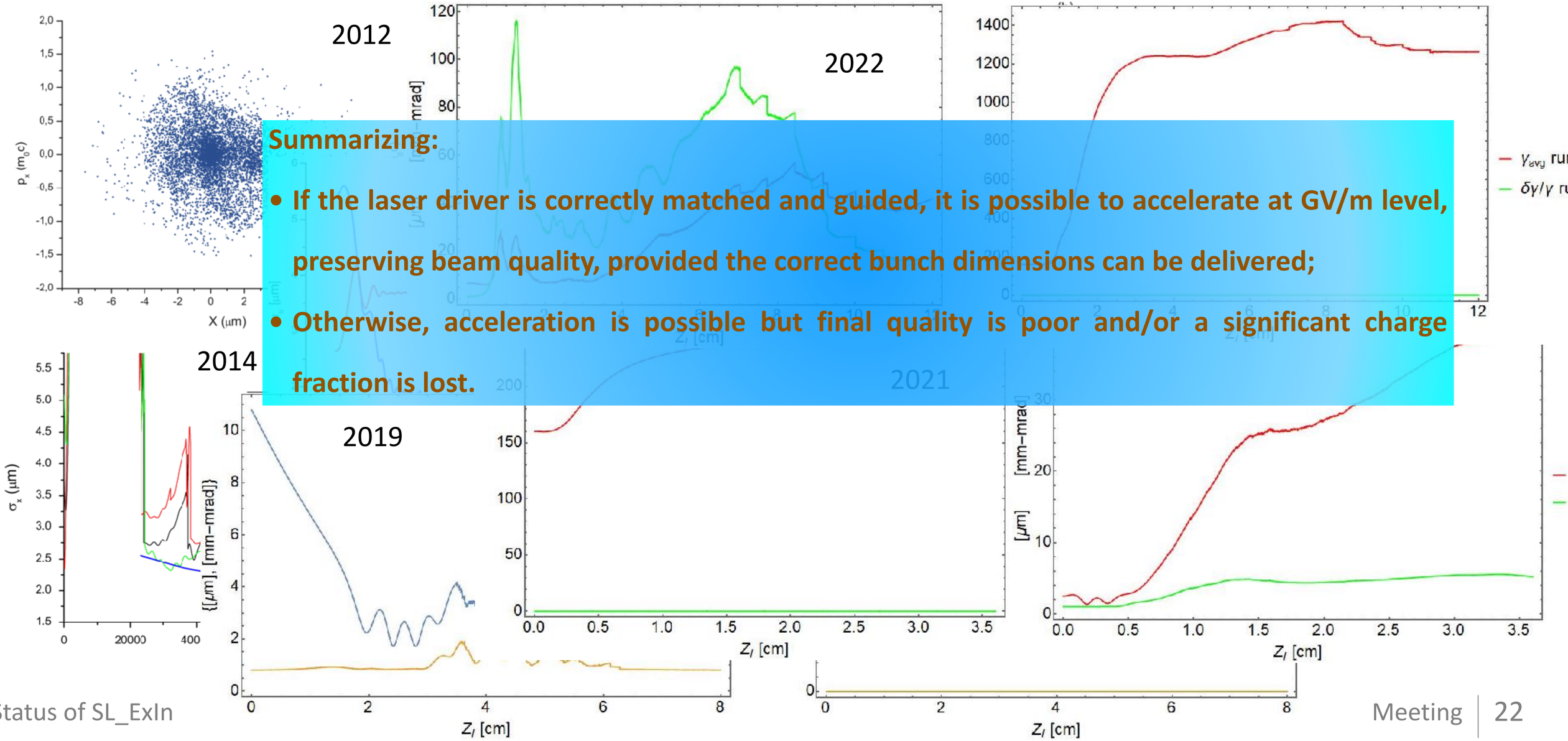
A.R. Rossi[a,*], A. Bacci[a], M. Belleveglia[b], E. Chiadroni[b], A. Cianchi[c,b], G. Di Pirro[b], M. Ferrario[b], A. Gallo[b], G. Gatti[b], C. Maroli[d], A. Mostacci[e,b], V. Petrillo[d,a], L. Serafini[a], P. Tomassini[d], C. Vaccarezza[b]

Nuclear Instruments and Methods in Physics Research A 740 (2014) 60–66
ELSEVIER Contents lists available at ScienceDirect Nuclear Instruments and Methods in Physics Research A journal homepage: www.elsevier.com/locate/nima

The External-Injection experiment at the SPARC_LAB facility

Andrea R. Rossi[a,*], Alberto Bacci[a], Marco Belleveglia[b], Enrica Chiadroni[b], Alessandro Cianchi[c,b], Giampiero Di Pirro[b], Massimo Ferrario[b], Alessandro Gallo[b], Giancarlo Gatti[b], Cesare Maroli[d], Andrea Mostacci[e,b], Vittoria Petrillo[d,a], Luca Serafini[a], Paolo Tomassini[d], Cristina Vaccarezza[b]

Many setups investigated



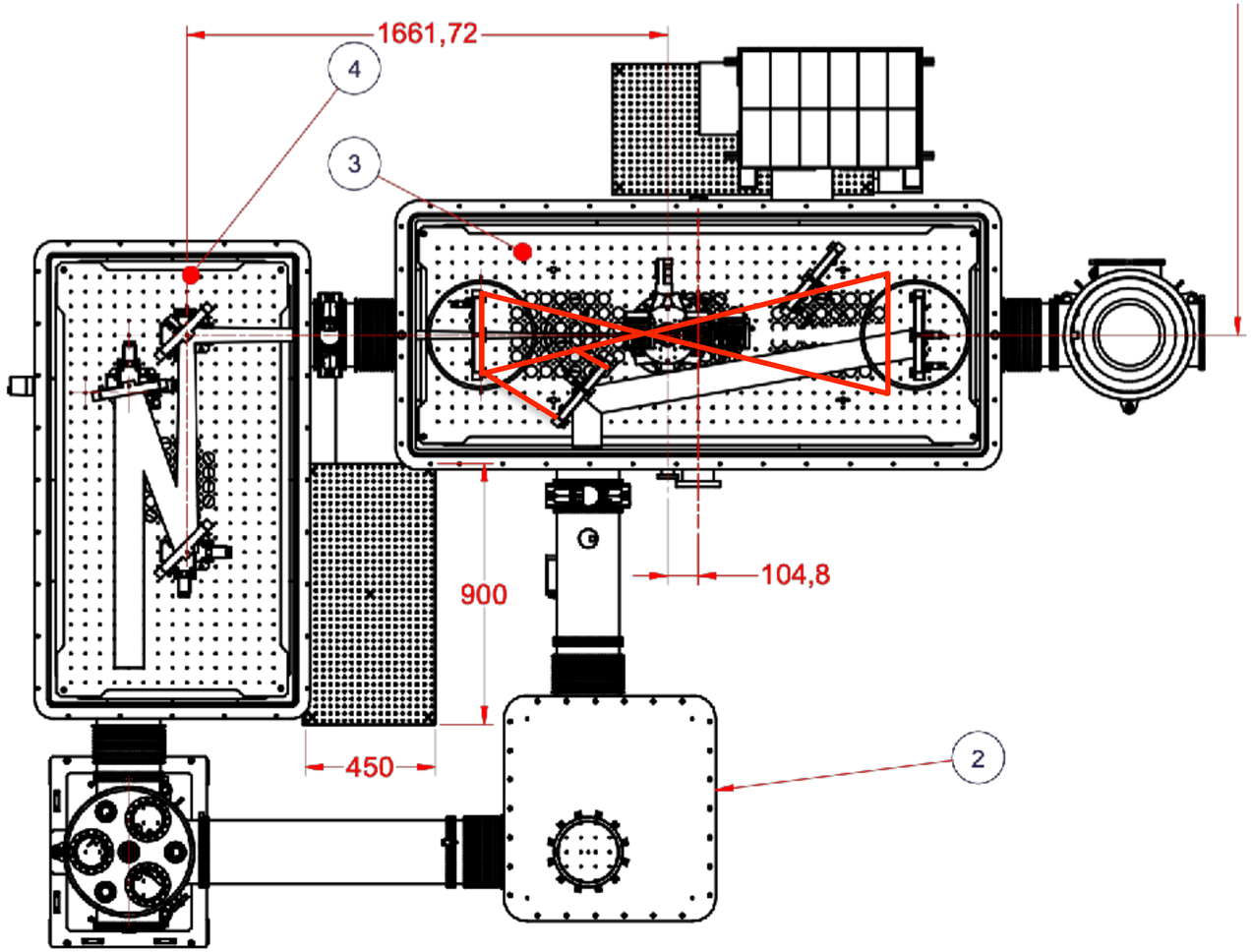
Summarizing:

- **If the laser driver is correctly matched and guided, it is possible to accelerate at GV/m level, preserving beam quality, provided the correct bunch dimensions can be delivered;**
- **Otherwise, acceleration is possible but final quality is poor and/or a significant charge fraction is lost.**

SL_ExIn & EuAPS

ExIn ISSUE (1): an opportunity for EuAPS

Since design of VPMQ is still ongoing, we have the opportunity to adapt them to EuAPS operation (ExIn, InIn)

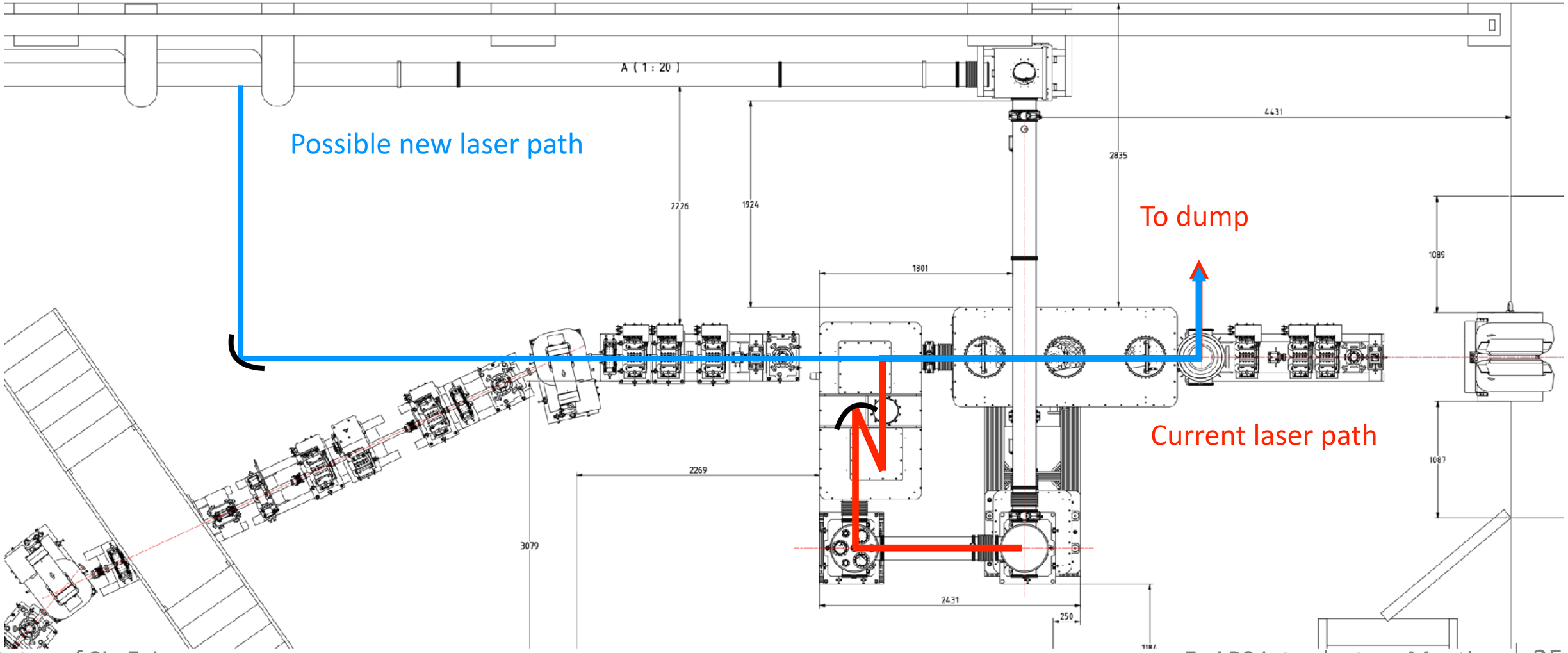


- Optimal ExIn operation requires a ***longer*** focal length parabola (more later on): the laser spot within the IC will be smaller, so that no modifications to VPMQs seem to be necessary

- InIn operation requires a ***shorter*** focal length parabola: matching VPMQs are not necessary, capture VPMQs require a larger bore.

ExIn ISSUE (2): an opportunity from EuAPS

In the present configuration, the parabola focal length is too short, preventing correct laser matching and guiding at nominal working point value.

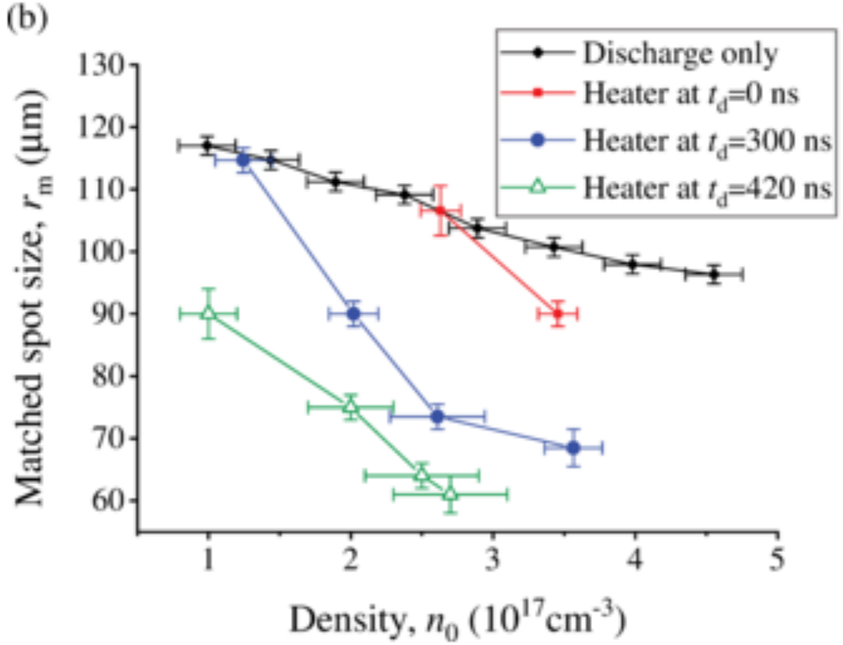


ExIn ISSUE (3): an opportunity from EuAPS

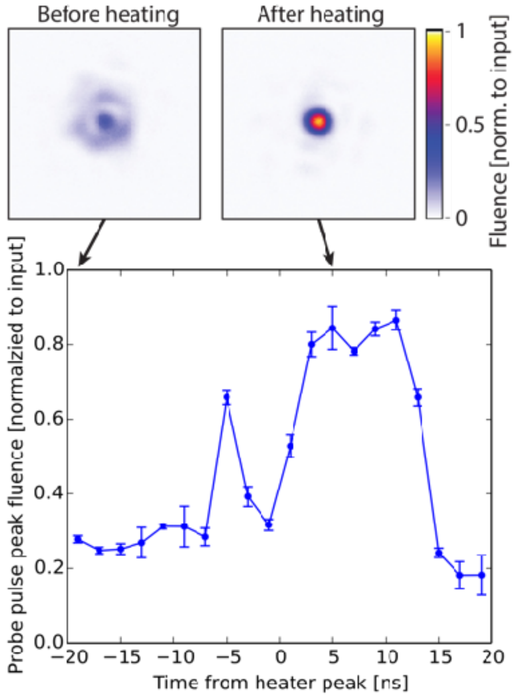
The combination of capillary radius and plasma nominal density do not return the correct transverse profile to guide laser at the nominal radius value, unless capillary radius is rather small (< 100 μm).

Possible solutions:

- a laser heater (PHYSICS OF PLASMAS 20, 020703 (2013))



Phys. Rev. Lett. **122**, 084801 (2019)



Phys. Plasmas 27, 053102 (2020)

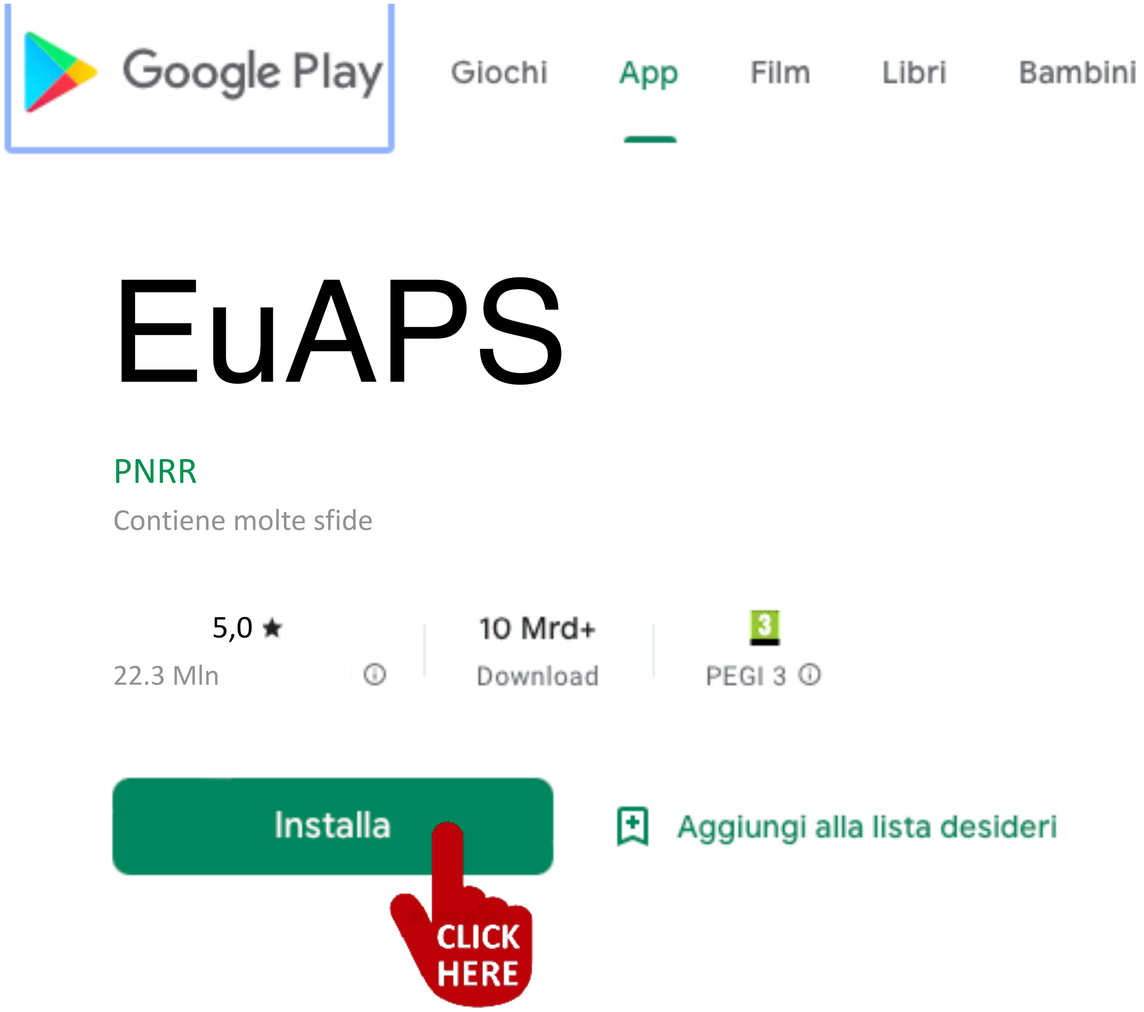
- filaments creation

A possible issue for EuAPS

Although vacuum pumping in the IC is sizable and gas specific, InIn operation may require a gas jet (high gas pressure), overwhelming pumping. The linac section can be isolated in InIn operation, but laser optics still requires low background gas levels ($\lesssim 10^{-5}$ mbar). Options:

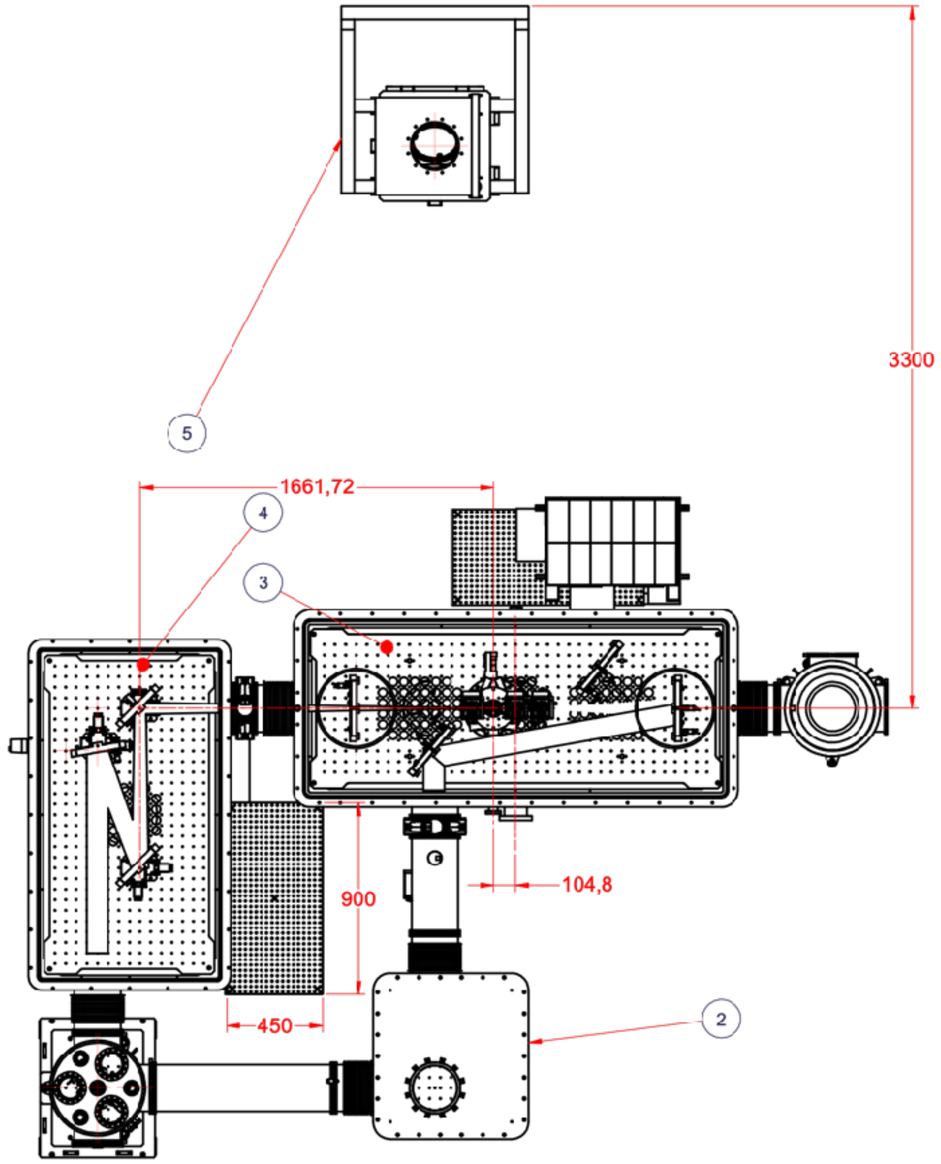
- Avoid gas jet and perform InIn in a capillary
  - ✓ Lower pressure and directional leakage
  - ✓ Allows more control on laser propagation (guiding)
  - - Guiding is less straightforward than self focusing (matching, capillary damage,…)
  - - Implementation of control over InIn may be a bit more difficult
- Enclose the plasma target in a gas blocking structure
  - ✓ Allow operation both with gas jet and capillary
  - - Effectiveness must be demonstrated

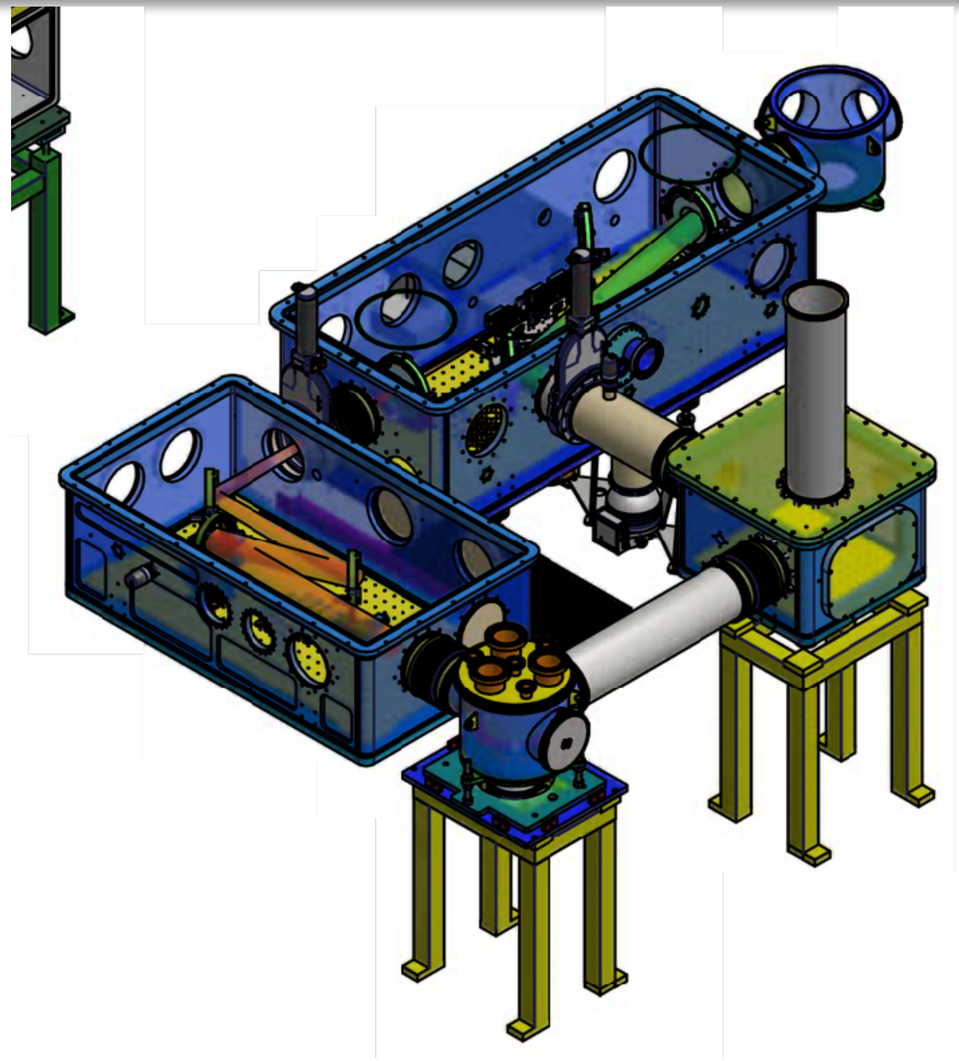
Thank you


Google Play
Giochi
App
Film
Libri
Bambini
EuAPS
PNRR
Contiene molte sfide
5,0 ★
22.3 Mln
10 Mrd+
Download
3
PEGI 3
Installa
Aggiungi alla lista desideri
CLICK HERE

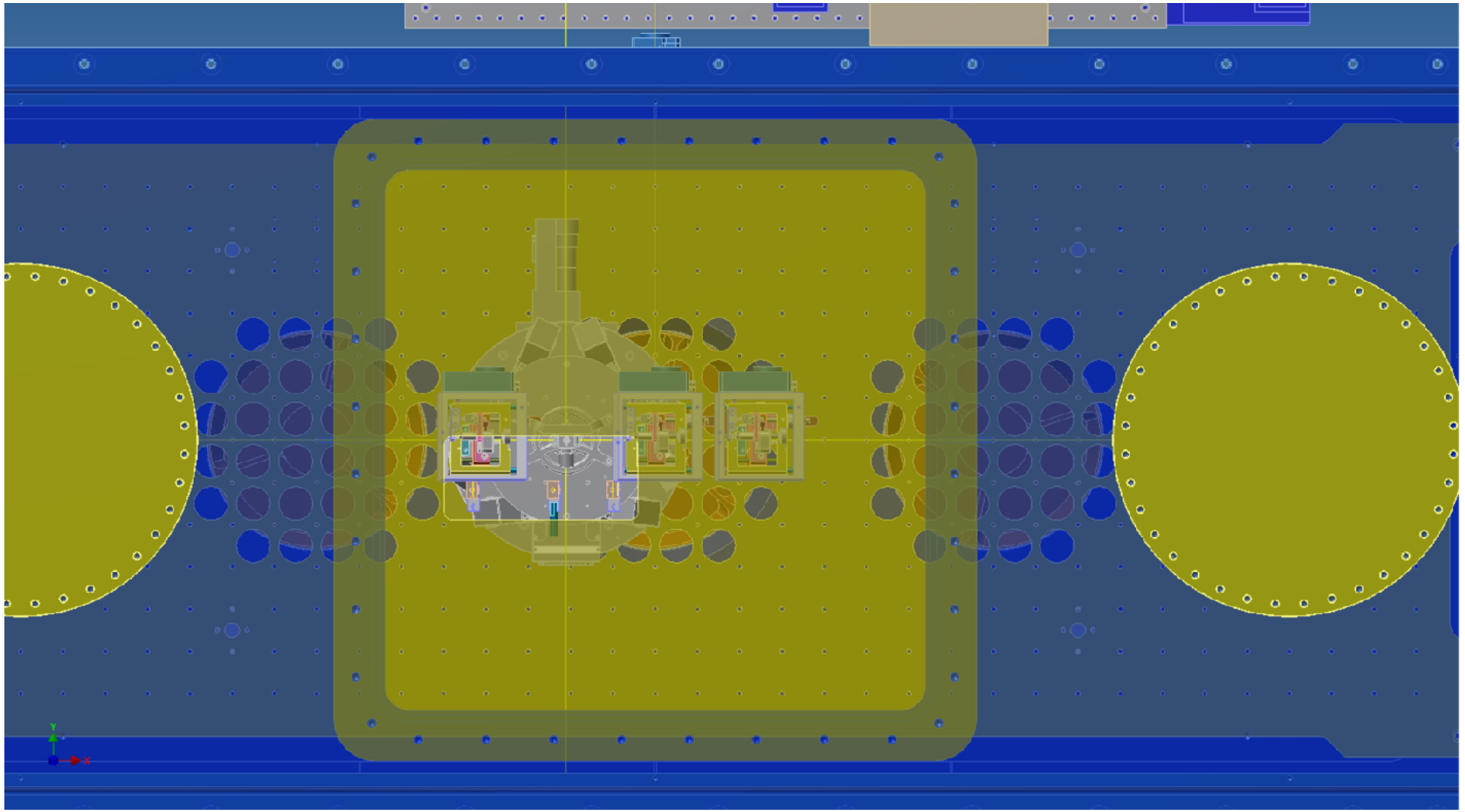
BACKUP SLIDES

Interaction area

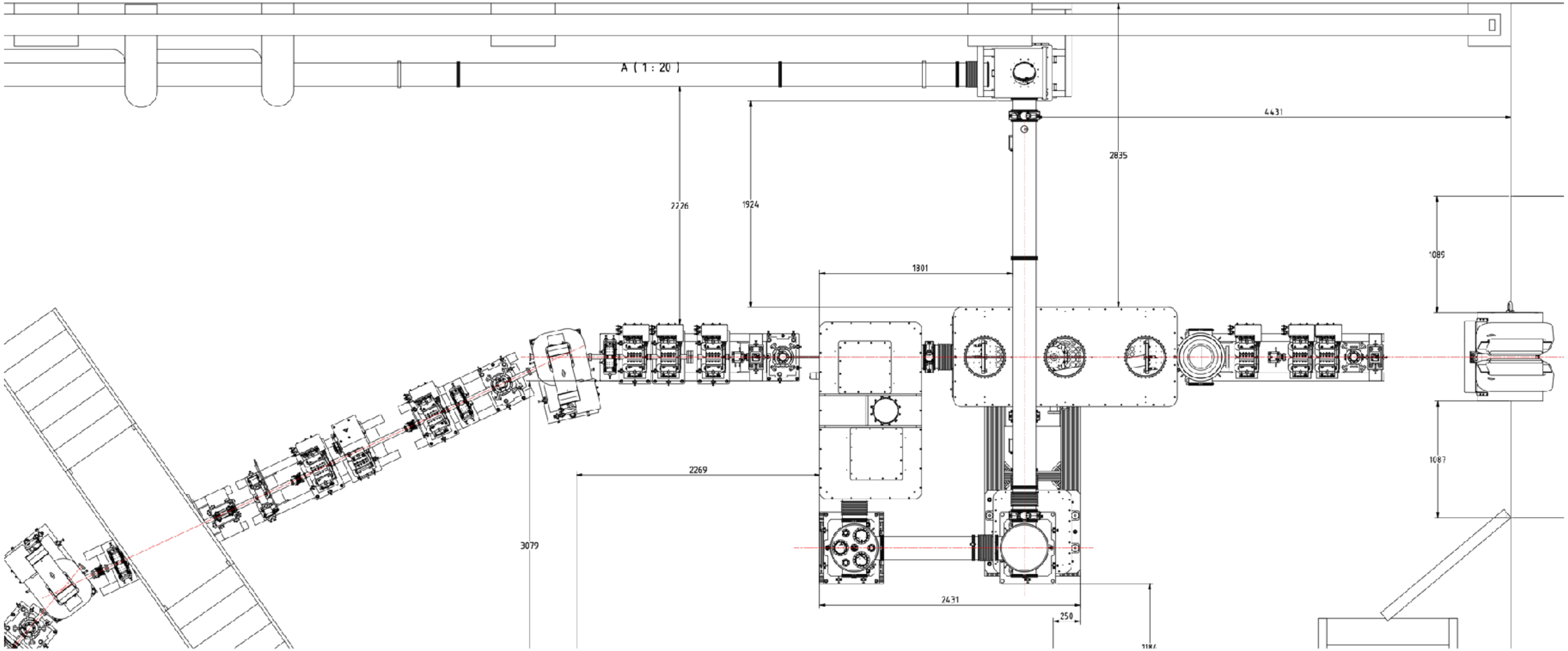




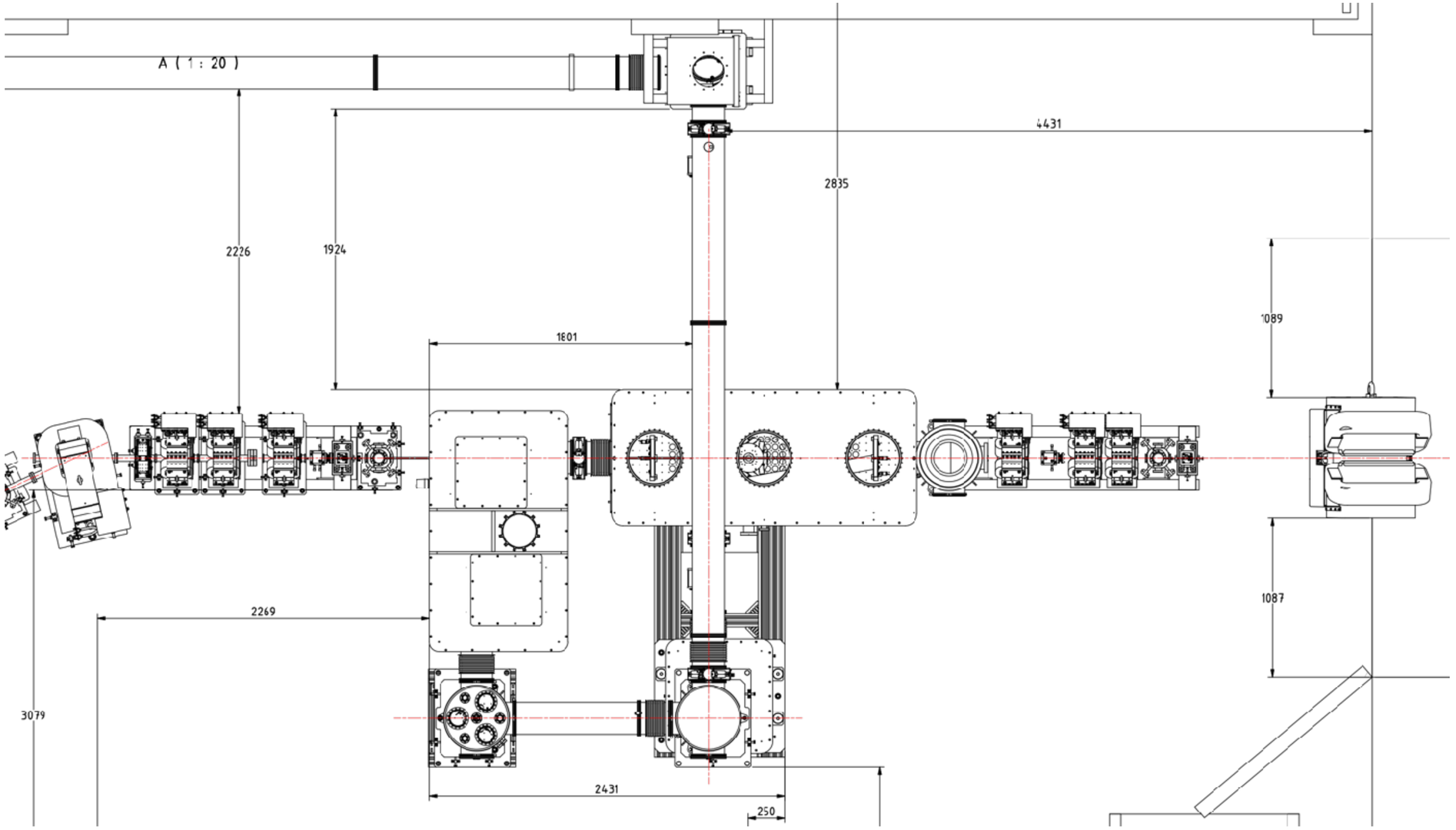
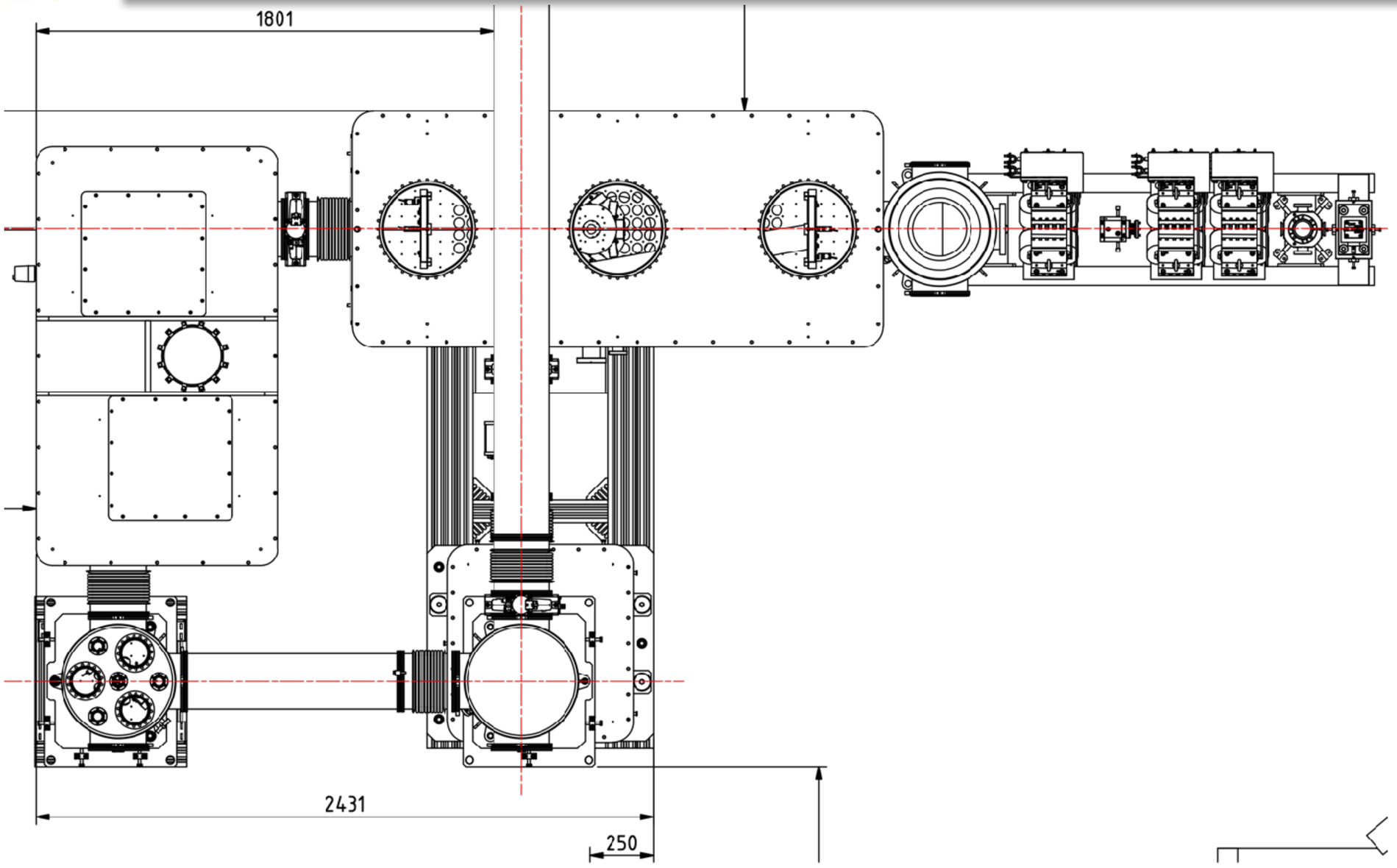
Interaction chamber



Layout



Layout 2



Layout 3