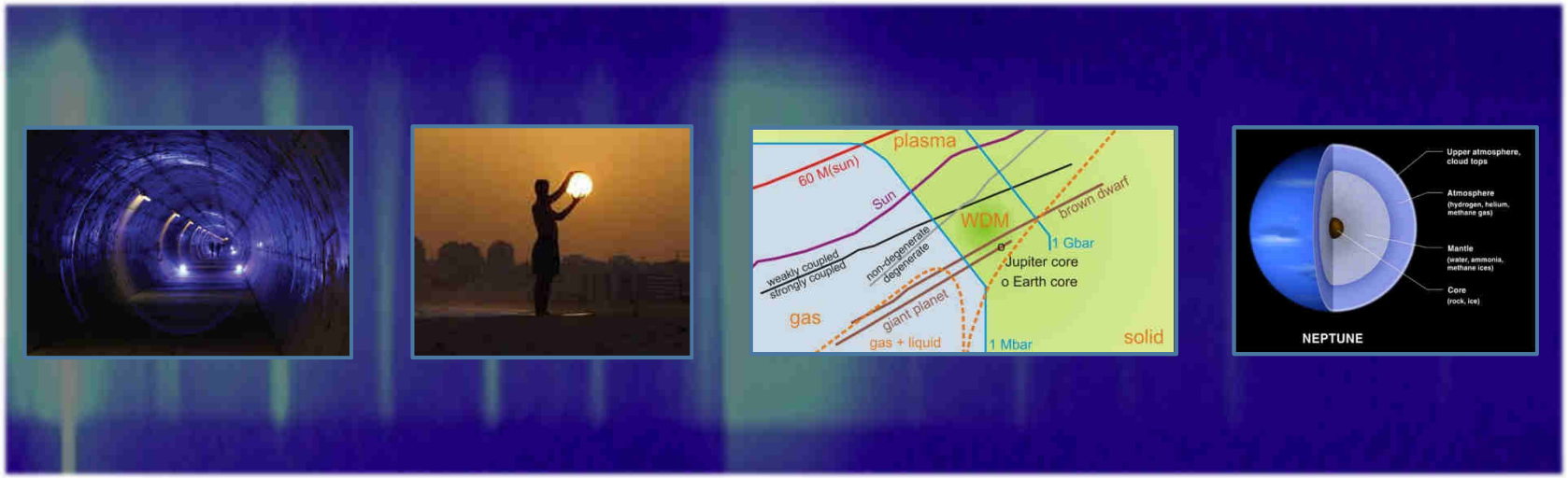
Experimental environment with optical lasers in 2020

Motoaki Nakatsutsumi
European XFEL, HED instrument
On behalf of HED instrument and HiBEF user consortium

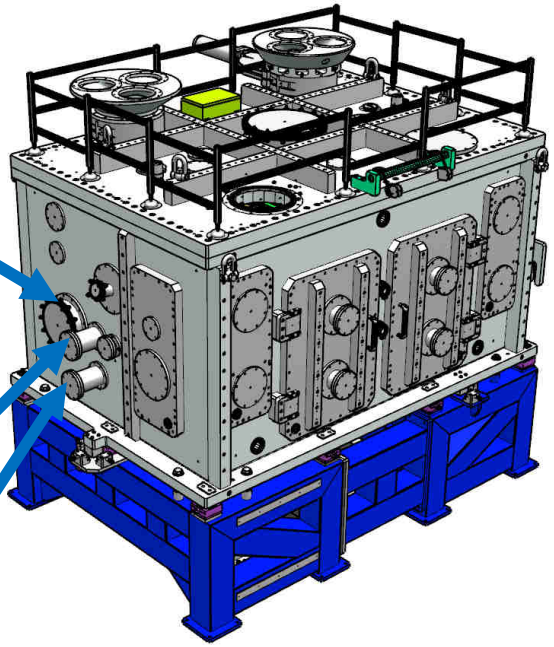
22th Jan. 2019, Satellite meeting:
Early science at HED and status of HIBEF contributions

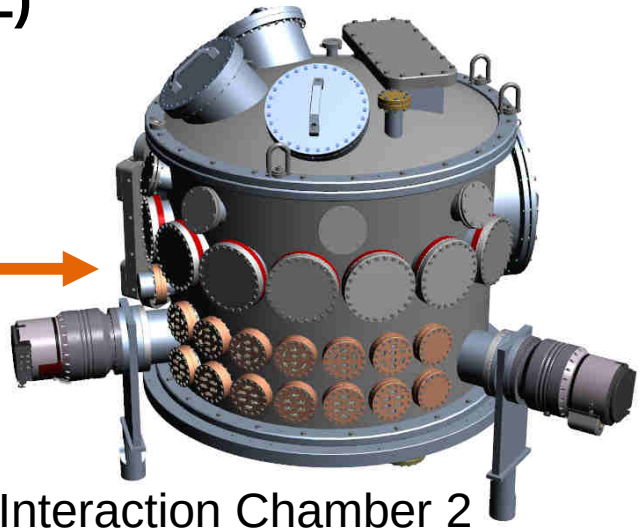


Three optical lasers

- **Pump-Probe (PP-OL)**
  - 2 (0.2) mJ, 0.1 (4.5) MHz, 15 - 300 fs (800 nm)
  - 40 (1) mJ, 0.1 (4.5) MHz, ~1 ps (1030 nm)
  - ≥ 10^{17} W.cm^{-2}
- **Amplitude (High-intensity: HI-OL)**
  - 7 J, 40 fs, ≥ 5 Hz on sample
  - > 10^{20} W/cm^2 – multi 100TW
- **DiPOLE (High-Energy: HE-OL)**
  - Max. 100 J (ω), 2–15 ns, 1 – 10 Hz

Interaction Chamber 1

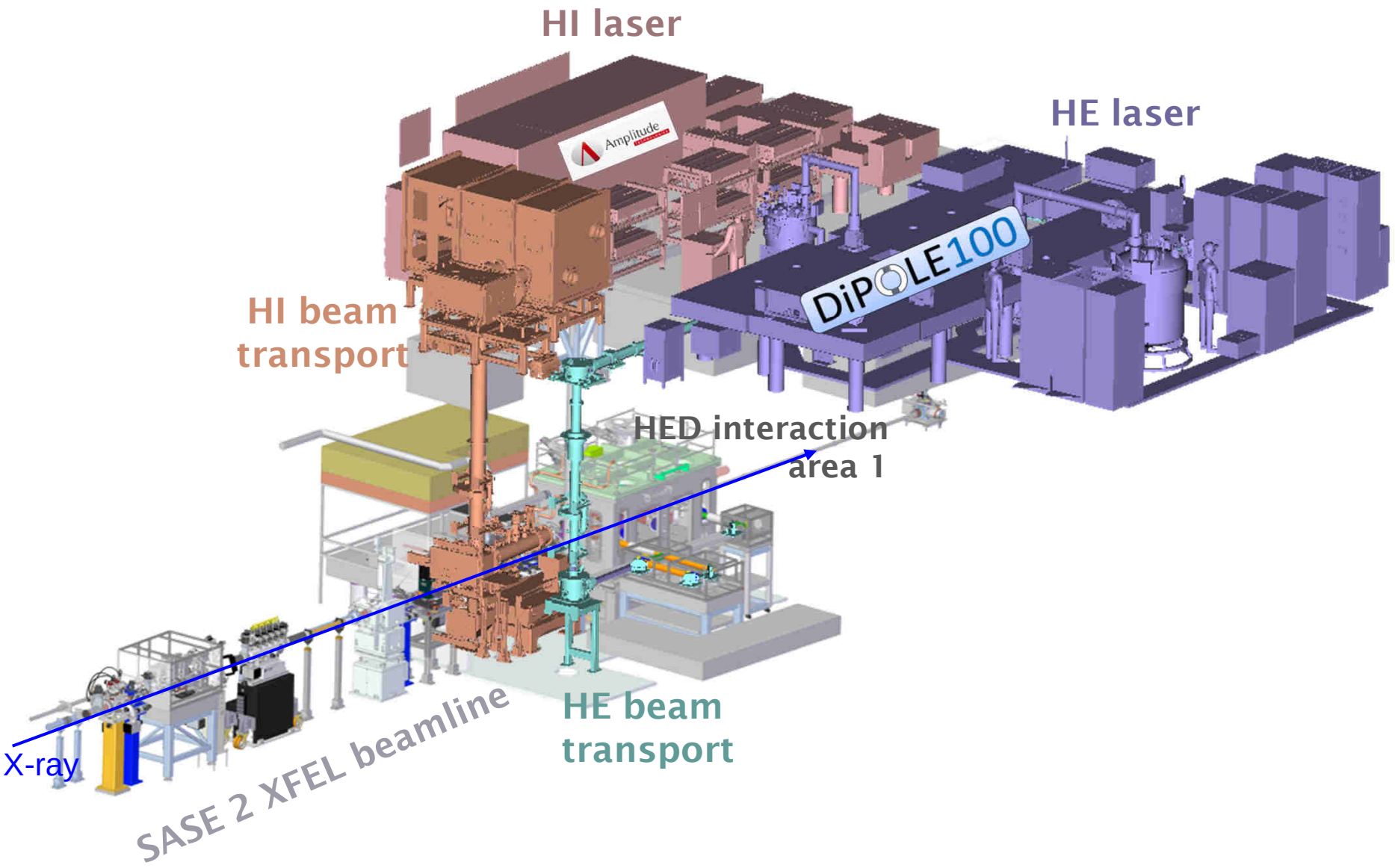




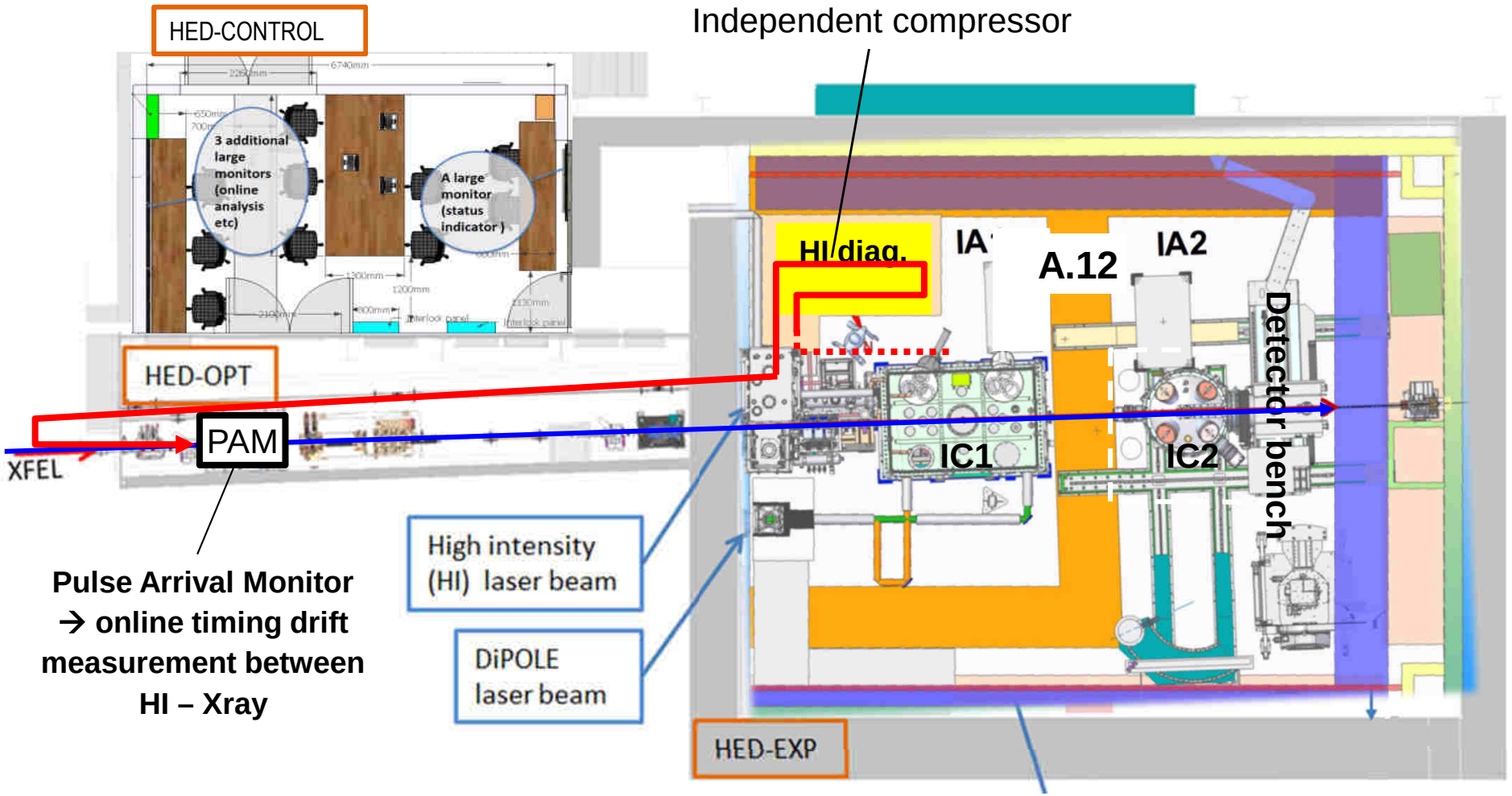
Interaction Chamber 2

High-intensity optical laser (HI-OL)

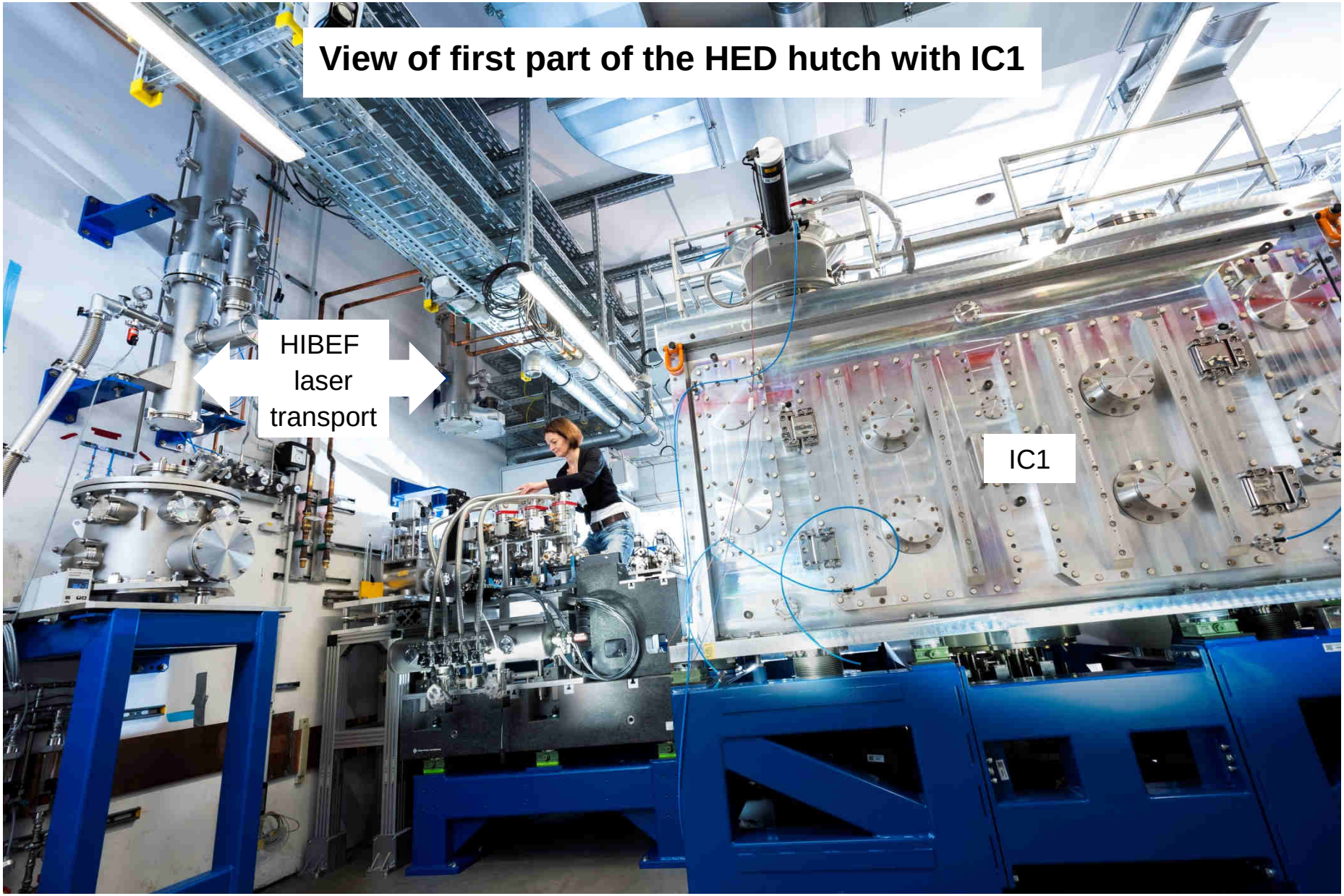
Amplitude technology


HI laser
HE laser
Amplitude
DiPOLE100
HI beam transport
HED interaction area 1
HE beam transport
X-ray
SASE 2 XFEL beamline

Top view

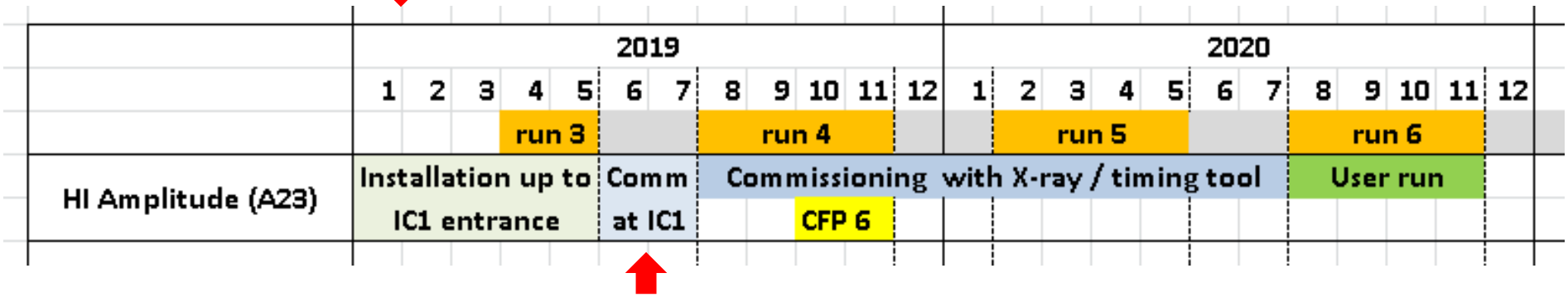

Pickup probe for PAM and probe.
Independent compressor
HED-CONTROL
3 additional large monitors (online analysis etc)
A large monitor (status indicator)
HED-OPT
PAM
XFEL
HI diag.
IA
A.12
IA2
IC1
IC2
Detector bench
High intensity (HI) laser beam
DiPOLE laser beam
HED-EXP
Pulse Arrival Monitor → online timing drift measurement between HI – Xray

View of first part of the HED hutch with IC1



HI-OL plan

We are here



Commissioning at sample location (summer shutdown)

Mid-February

- on-site acceptance test / laser handed over

March-May

- Compressor optics, deformable mirror, wavefront, RGA
- Pickup probe transport, compressor
- Laser diagnostics installation and commissioning
- PAM optics installation

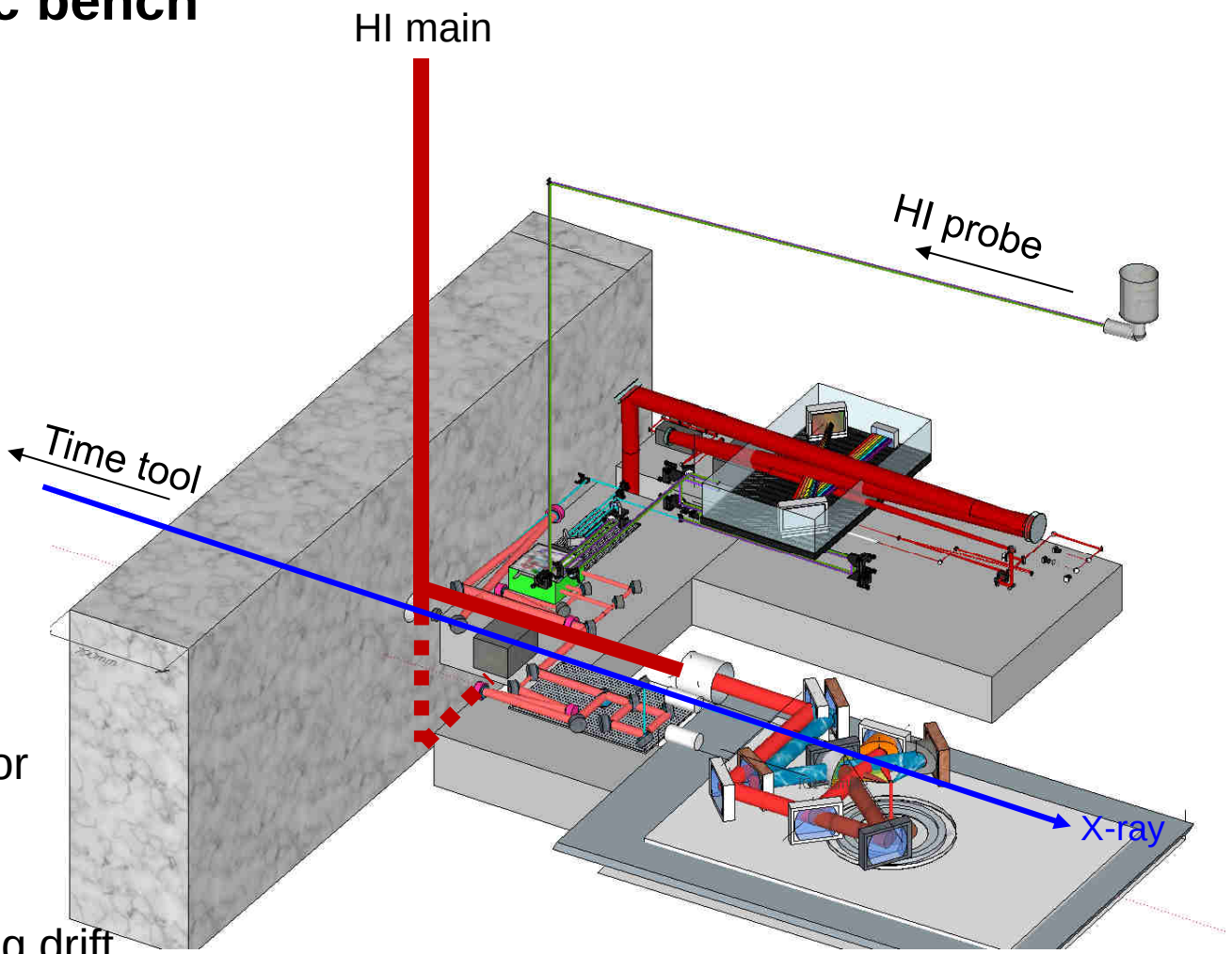
HI-OL diagnostic bench

HI diags.

- Near & far field
- Spectrum
- Energy
- Pulse duration
- Temporal profile
- Spectral phase
- Wavefront

HI probe

- Delay lines
- Probe compressor
- Image relay
- SHG/THG
- Probe-main timing drift



Design	90% done
Purchasing	85%

HI-OL diagnostic bench

HI diags.

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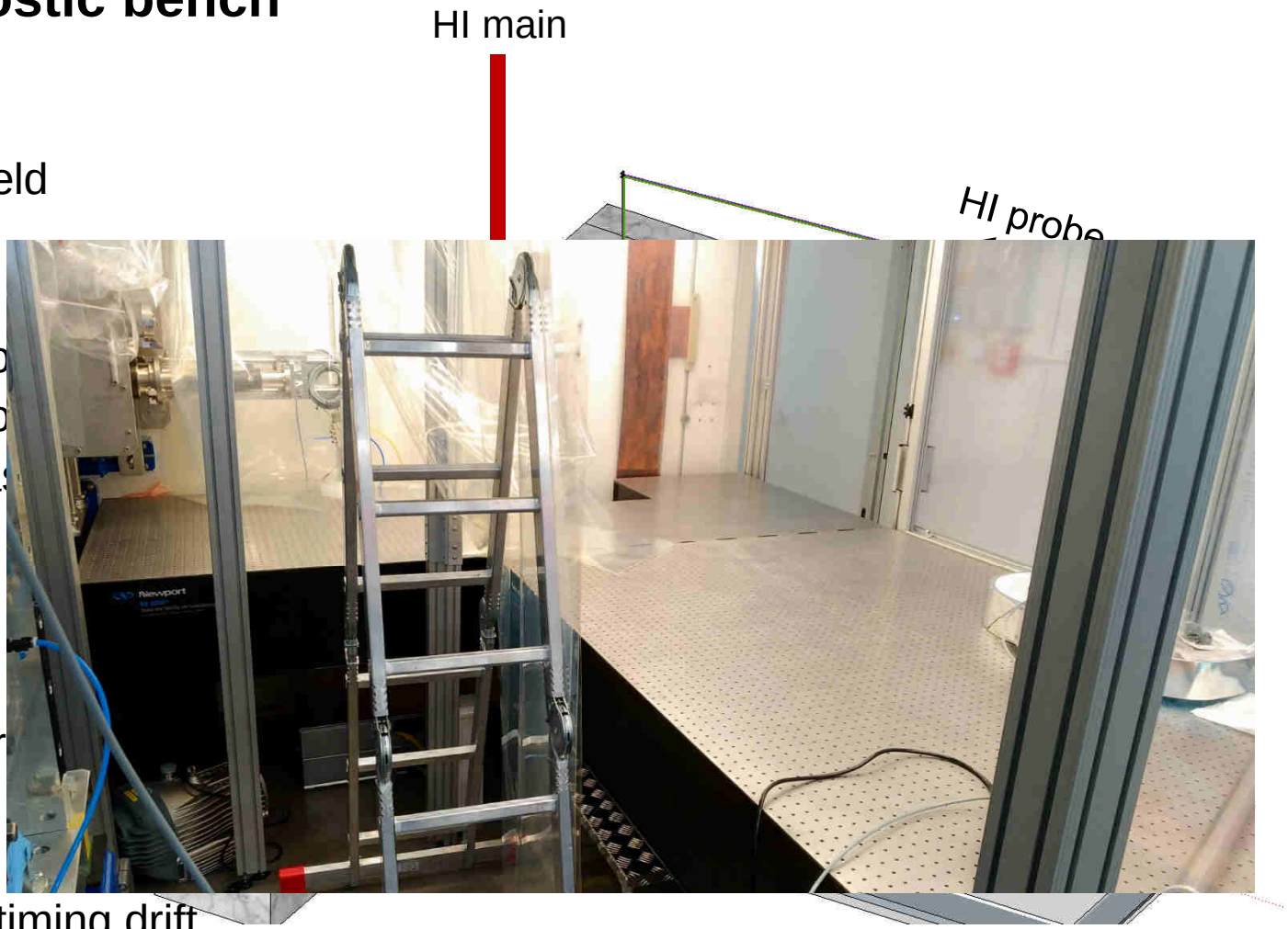
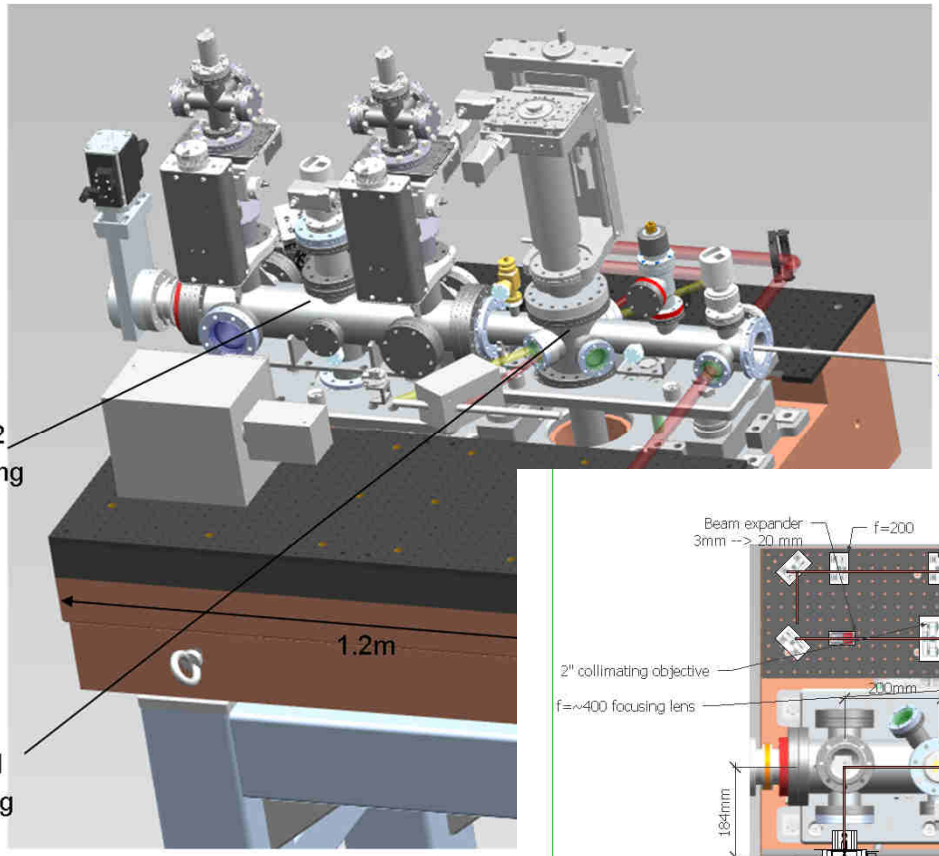
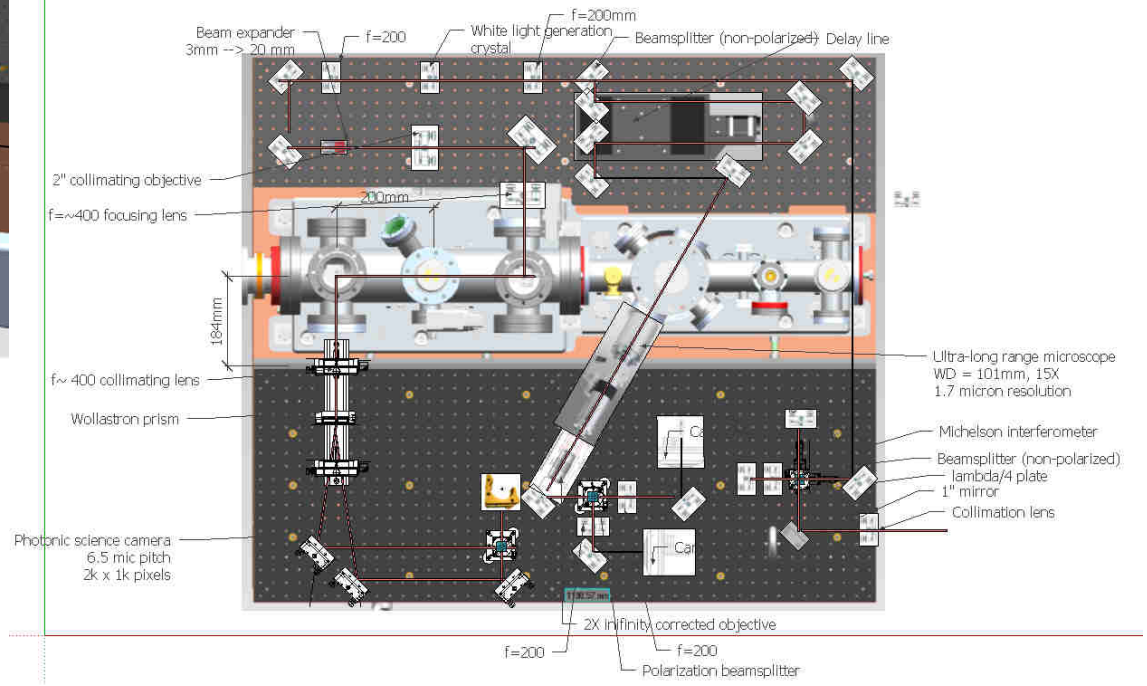


Design	90% done
Purchasing	85%

PAM (pulse arrival monitor: time tool)





Design	100% done
Purchasing	95% done
(laser window and sample mount)	
Optic installation starts	

HI diags.

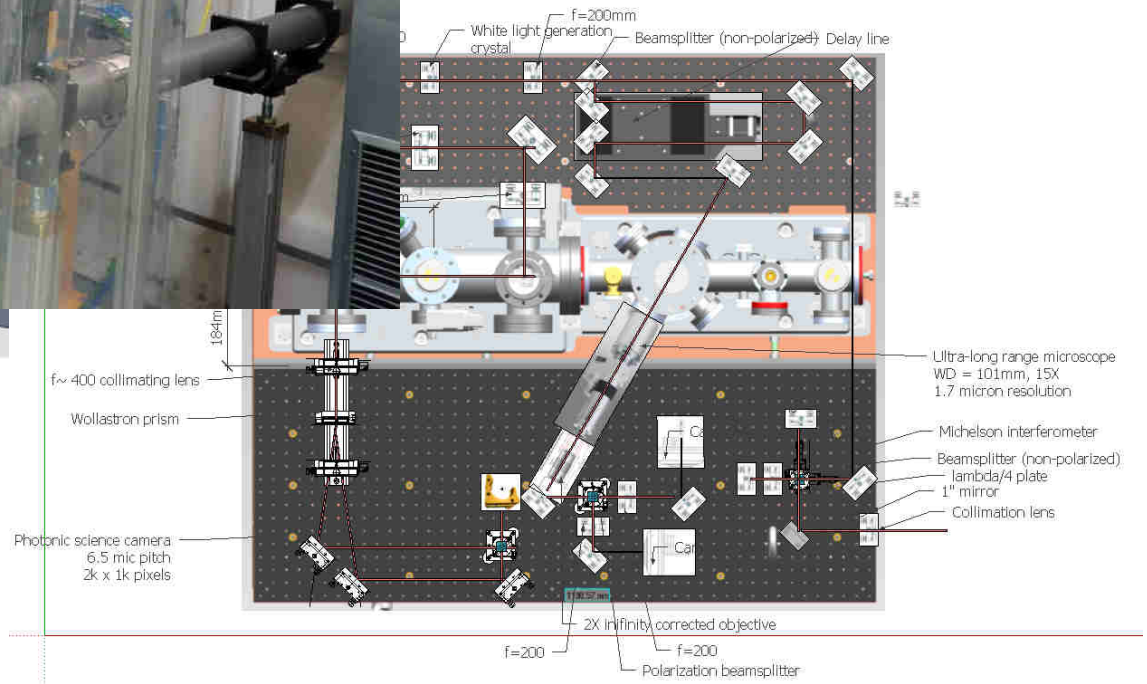
- ~10 m upstream
- Before X-ray Att., CRL3
- HI – X-ray or PP – X-ray
- 2 techniques

PAM (pulse arrival monitor: time tool)

HI diags.

- ~10 m upstream
- Before X-ray Att., CRL3
- HI – X-ray or PP – X-ray
- 2 techniques

X-ray



Design	100% done
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(laser window and sample mount)	
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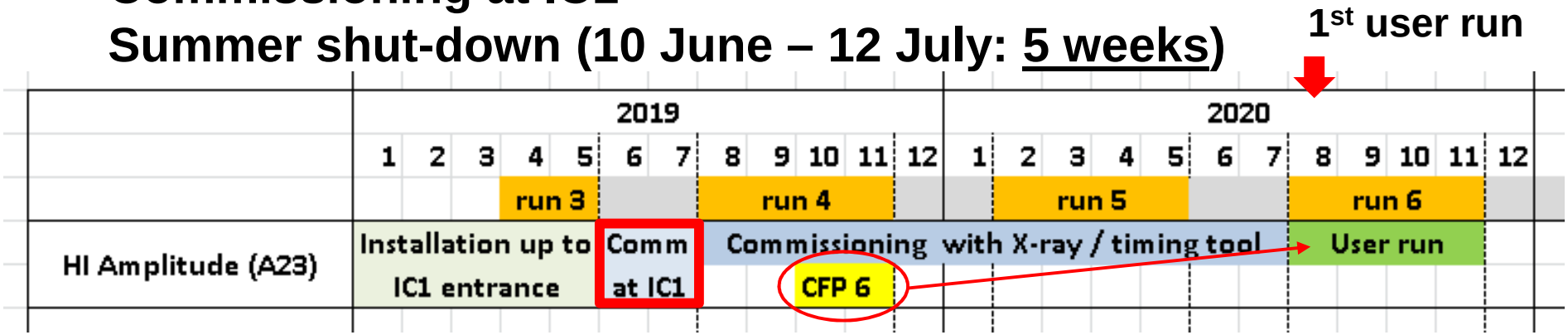
Commissioning at IC1
Summer shut-down (10 June – 12 July: 5 weeks)



1. Focus the beam at sample location. Characterization and optimization (4 wks)

- Place optics, stages. Beam alignment. OAP focus.
- Spot, enerygy, temporal profile, spectral phase
- With fully amplified beam. Eventually in vac.

  ~7 J on sample, ~40 fs duration, ~ 4 µm FWHM spot with ~0.7 Strehl ratio,

2. Test shots with samples at high power (2wks)

- Particle / optical diagnostics
- EMP test. Performance of motors.

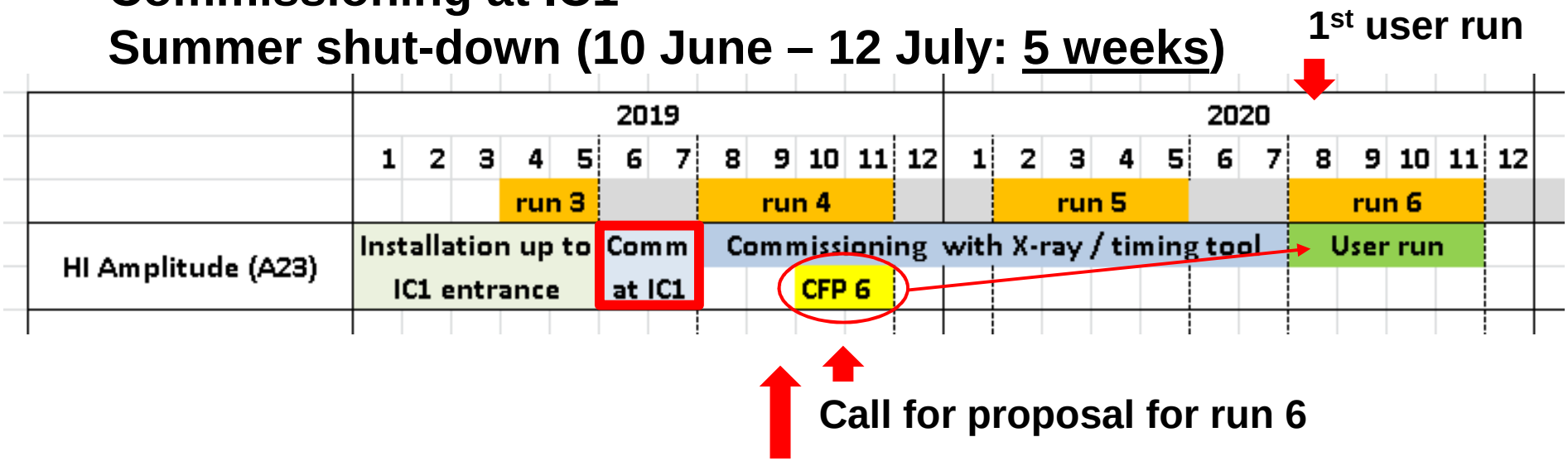
→ need help/contribution

3. Timing drift measurement between HI-probe and HI-main (2 wks)

- With optical cross-correlator

In parallel with other activities

Commissioning at IC1
Summer shut-down (10 June – 12 July: 5 weeks)



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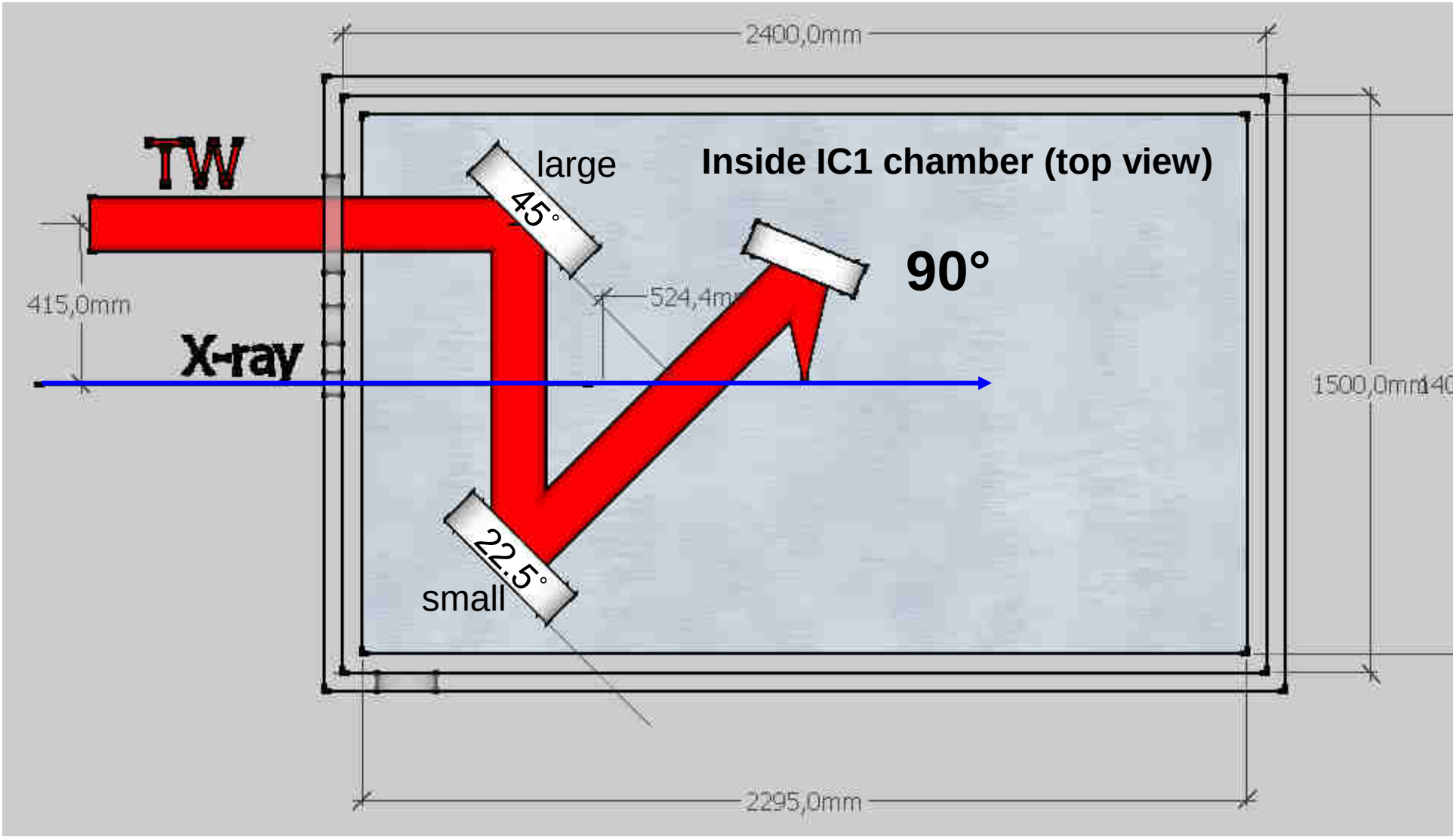
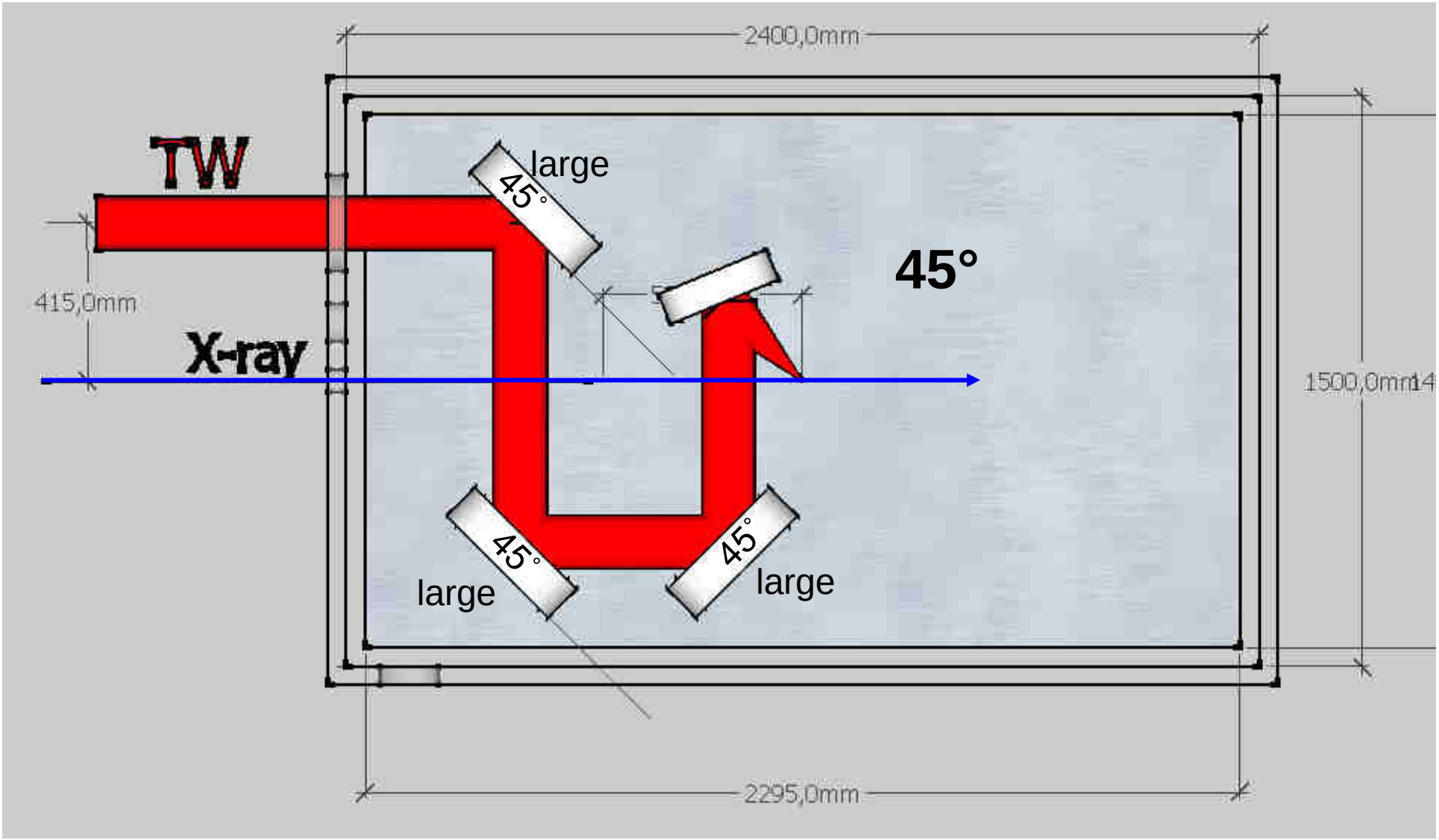
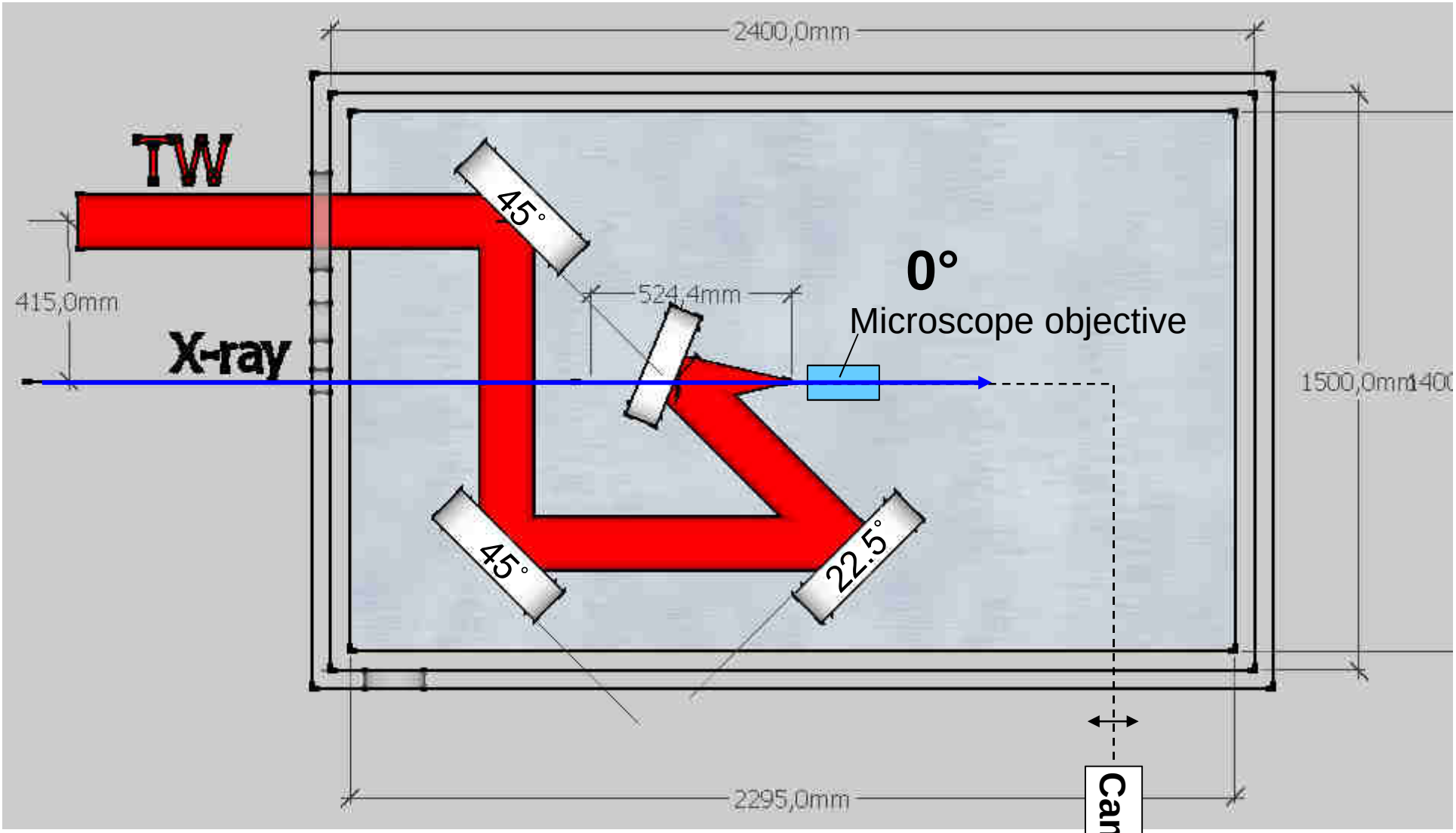
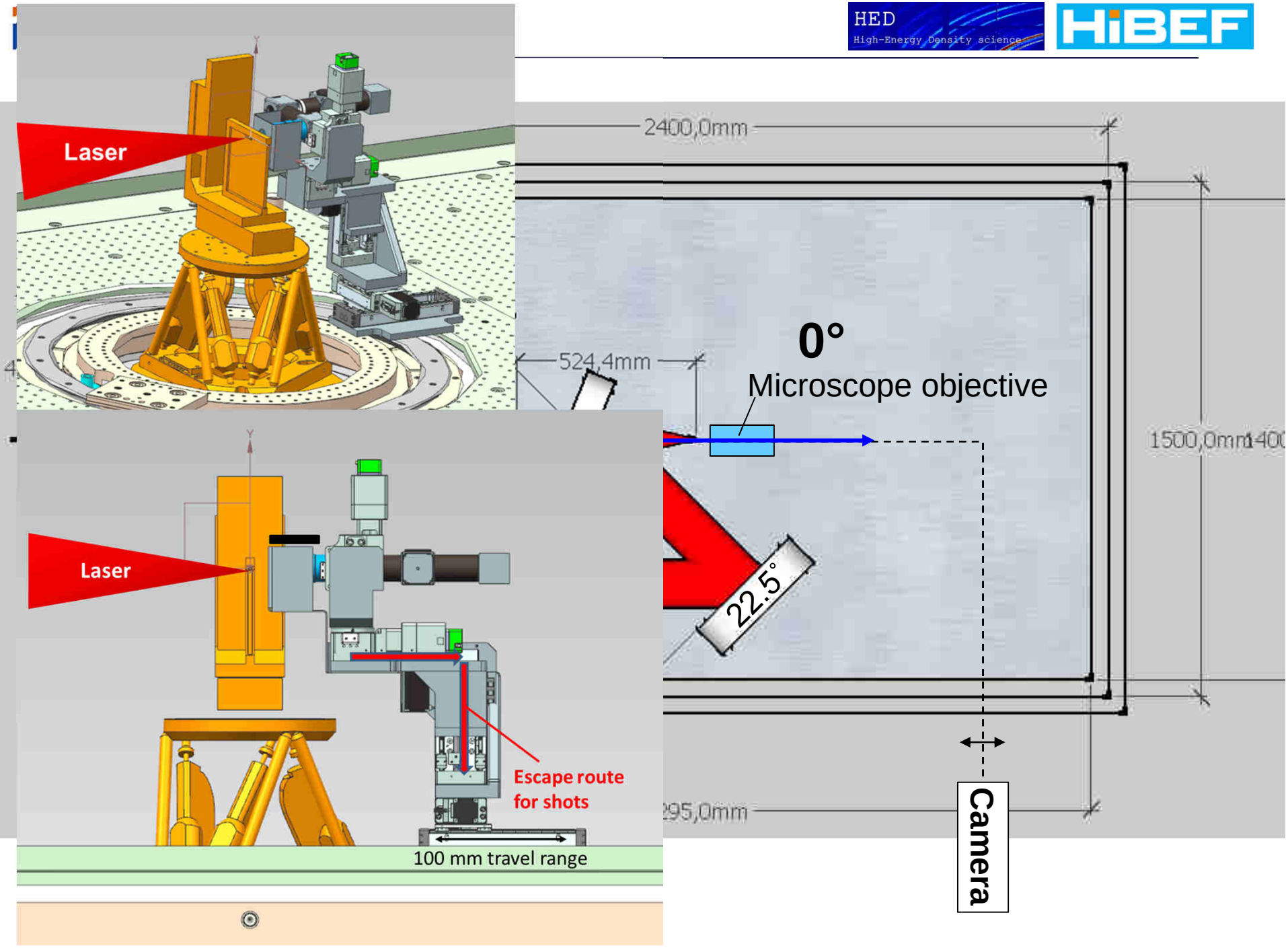
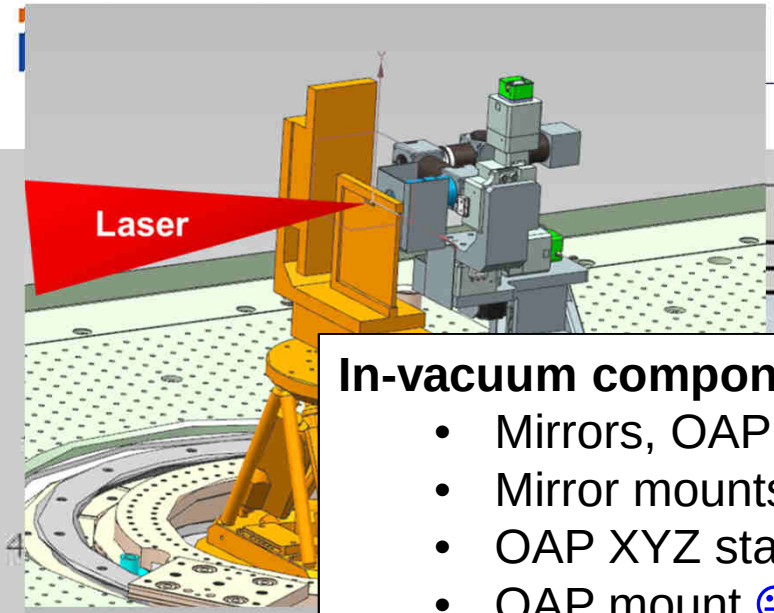

2400,0mm
TW
large
Inside IC1 chamber (top view)
45°
90°
415,0mm
524,4mm
X-ray
1500,0mm
22.5°
small
2295,0mm


2400,0mm
TW
large
45°
45°
415,0mm
X-ray
1500,0mm
45°
large
45°
large
2295,0mm


2400,0mm
TW
45°
415,0mm
524,4mm
0°
Microscope objective
X-ray
1500,0mm
45°
22,5°
2295,0mm
Camera


Laser
2400,0mm
524,4mm
0°
Microscope objective
1500,0mm
22.5°
Camera
Laser
Escape route
for shots
100 mm travel range



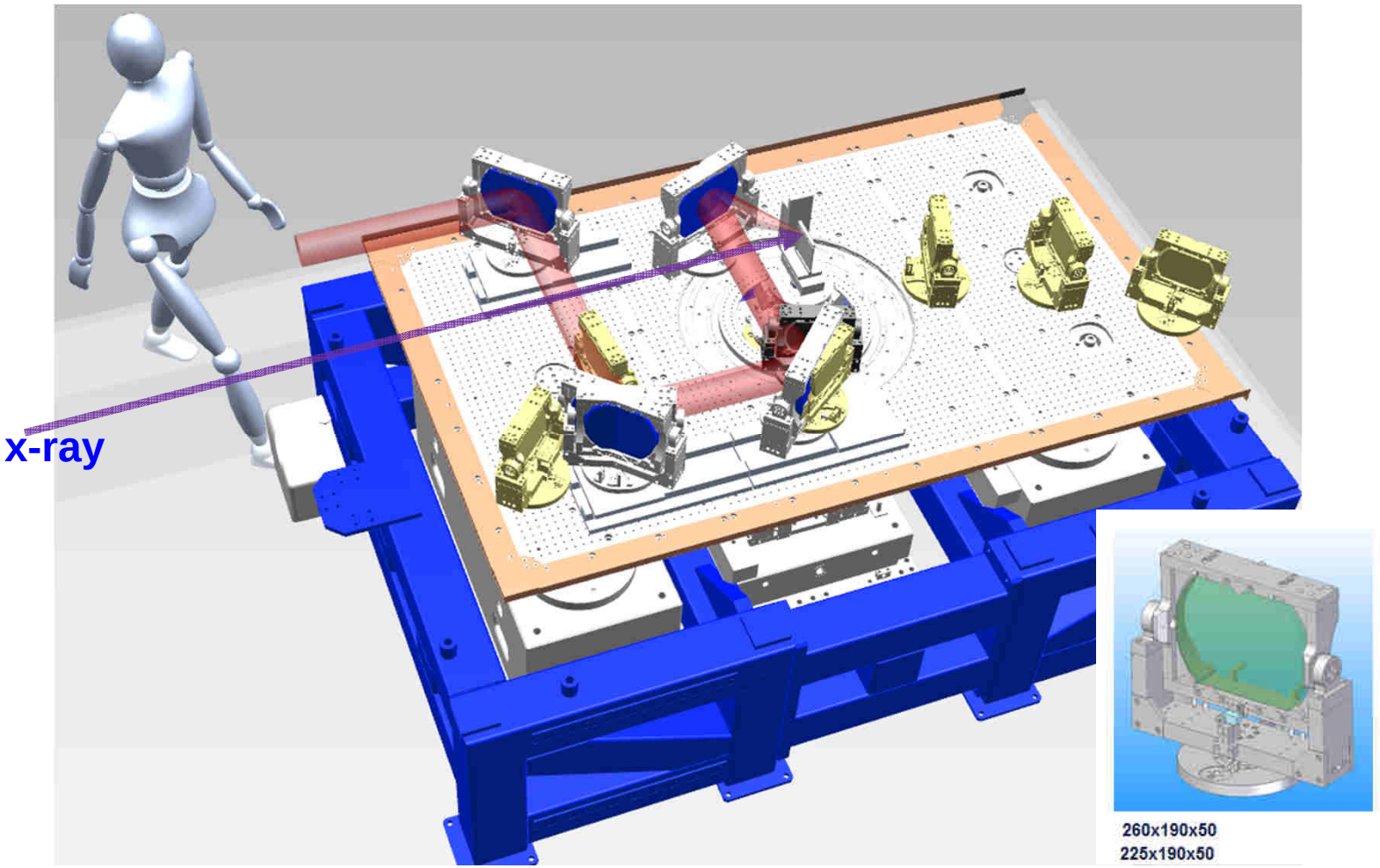
In-vacuum component (optics, optomechanics, stages): 75%

- Mirrors, OAP ☺
- Mirror mounts ☺
- OAP XYZ stages ☺
- OAP mount 😐
- In-vac stages 😐
- Debris shield ☹
- Integration of motors to Karabo ☹**?**

Diagnostics for test experiments: 30%

- Optical diagnostics 😐
- Particle diagnostics ☹

Example of HI laser transport in IC1



PP laser

Pump-Probe (PP) laser ‚set point' for HED instrument

λ	800nm	1030nm
τ_{FWHM}	15..300fs (nearly transform limited)	<1ps or 400ps (chirped)

Set point	max. f_{rep} [MHz]	E_{pulse} [mJ] @ 800nm	E_{pulse} [mJ] @ 1030nm
1	4.5	0.05	1
2	1	0.2	4
3	0.2	1	20
4	0.1	2	40

- 2 mJ, 15 fs, λ = 800 nm, <100 kHz
- 40 mJ, 1 ps, λ = 1030 nm, <100 kHz

- λ = 800 nm at up to ~ 300 fs (by narrowing the bandwidth)

Pump-Probe (PP) laser ‚set point' for HED instrument

λ	
τ_{FWHM}	15..300fs

2 mJ / 15 fs/ 5 µmϕ
→ > 10^{17} W.cm^{-2}

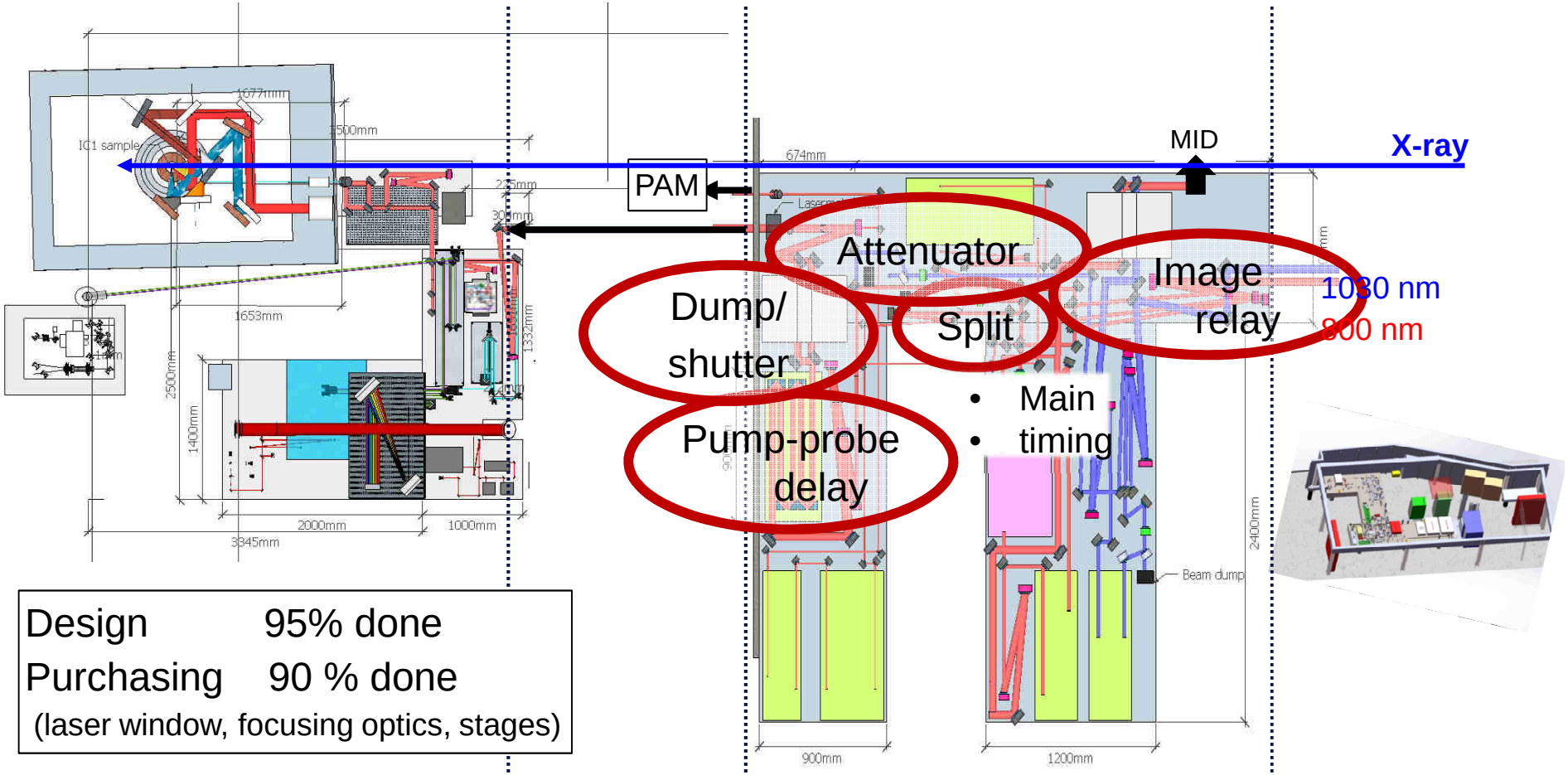
40 mJ / 1 ps
→ ~ 10^{17} W.cm^{-2}
@ 5 µmϕ
→ ≥ 10^{14} W.cm^{-2}
@ 100 µmϕ

Set point	max. f_{rep} [MHz]	E_{pulse} [mJ] @ 800nm	E_{pulse} [mJ] @ 1030nm
1	4.5	0.05	1
2	1	0.2	4
3	0.2	1	20
4	0.1	2	40

- 2 mJ, 15 fs, λ = 800 nm, <100 kHz
- 40 mJ, 1 ps, λ = 1030 nm, <100 kHz

- λ = 800 nm at up to ~ 300 fs (by narrowing the bandwidth)

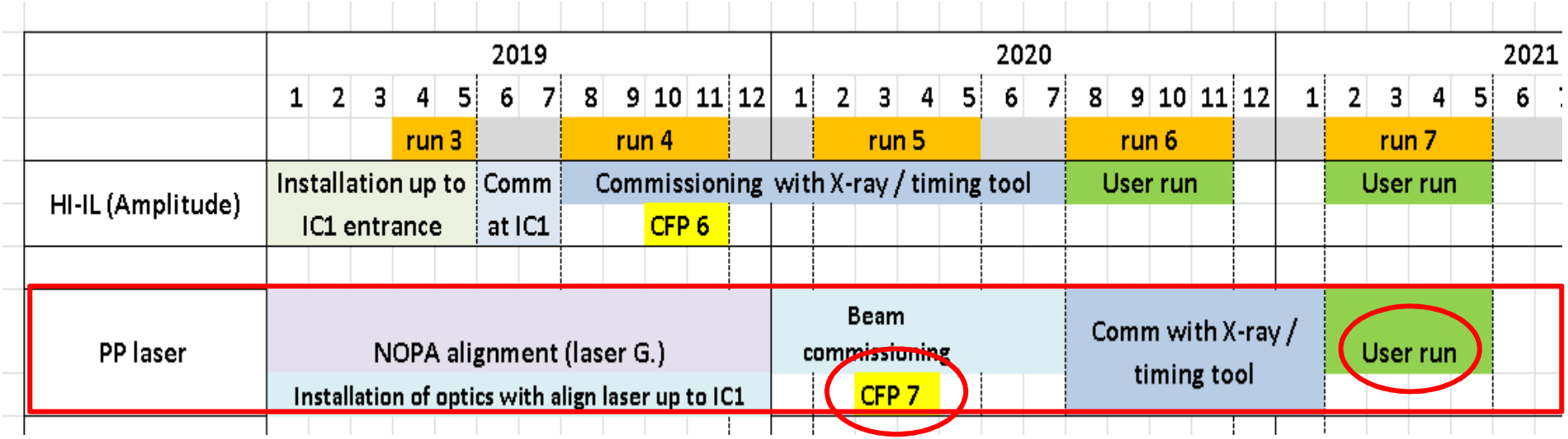
PP-OL transport



Design	95% done
Purchasing	90 % done
(laser window, focusing optics, stages)	

HED-EXP	HED-OPT	COM - LAS	SA2-LAS
Experiment	**Timing**	**Manipulation**	**Laser hutch**

PP-OL commissioning / operation schedule



End 2019:PP laser handed over to HED.

- Current best guess – in-parallel operation at all SASEs by OL group
- All optics can be placed with alignment laser
- Beam commissioning should be relatively straightforward

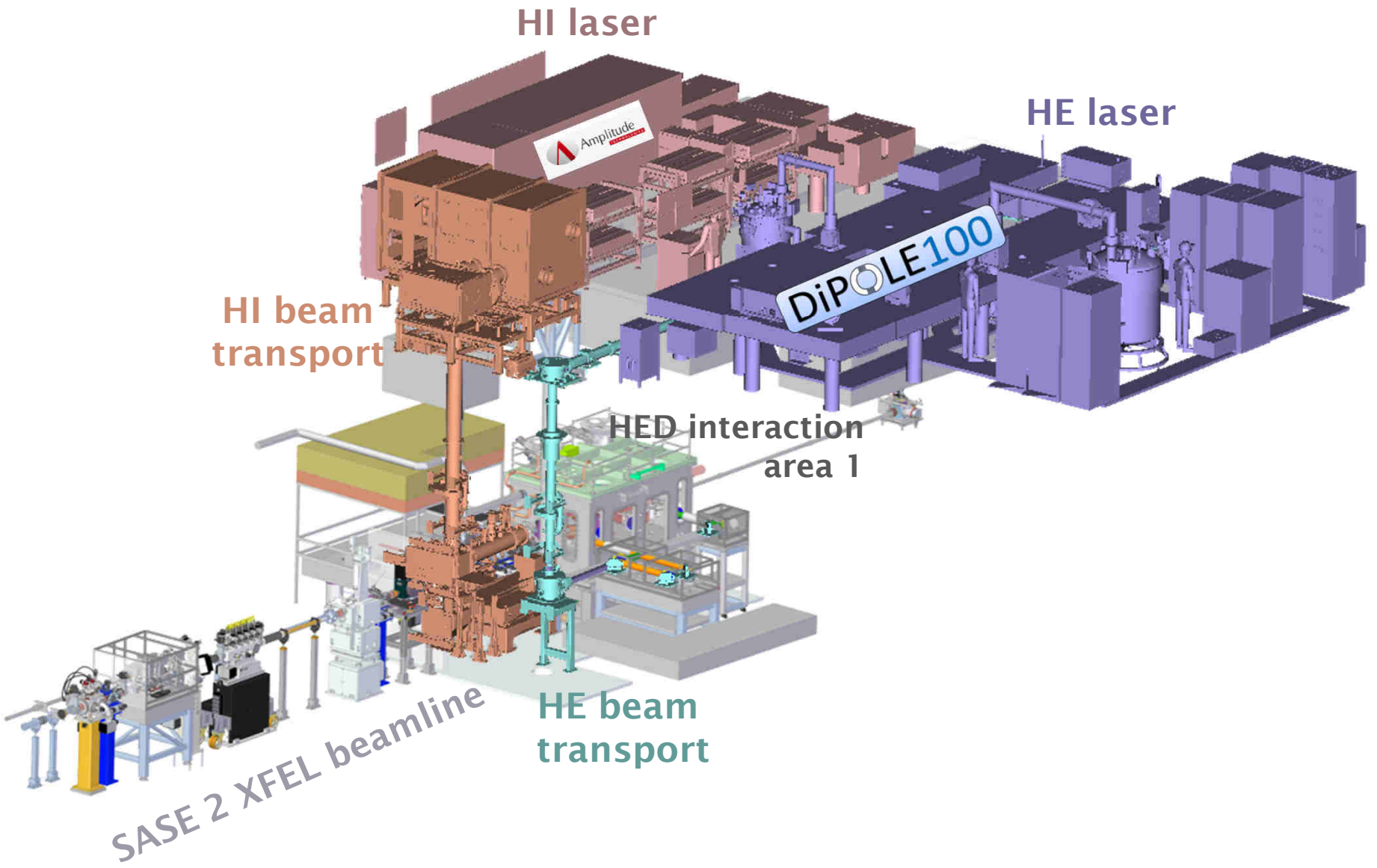
Science & Technology Facilities Council

HED High-Energy Density science

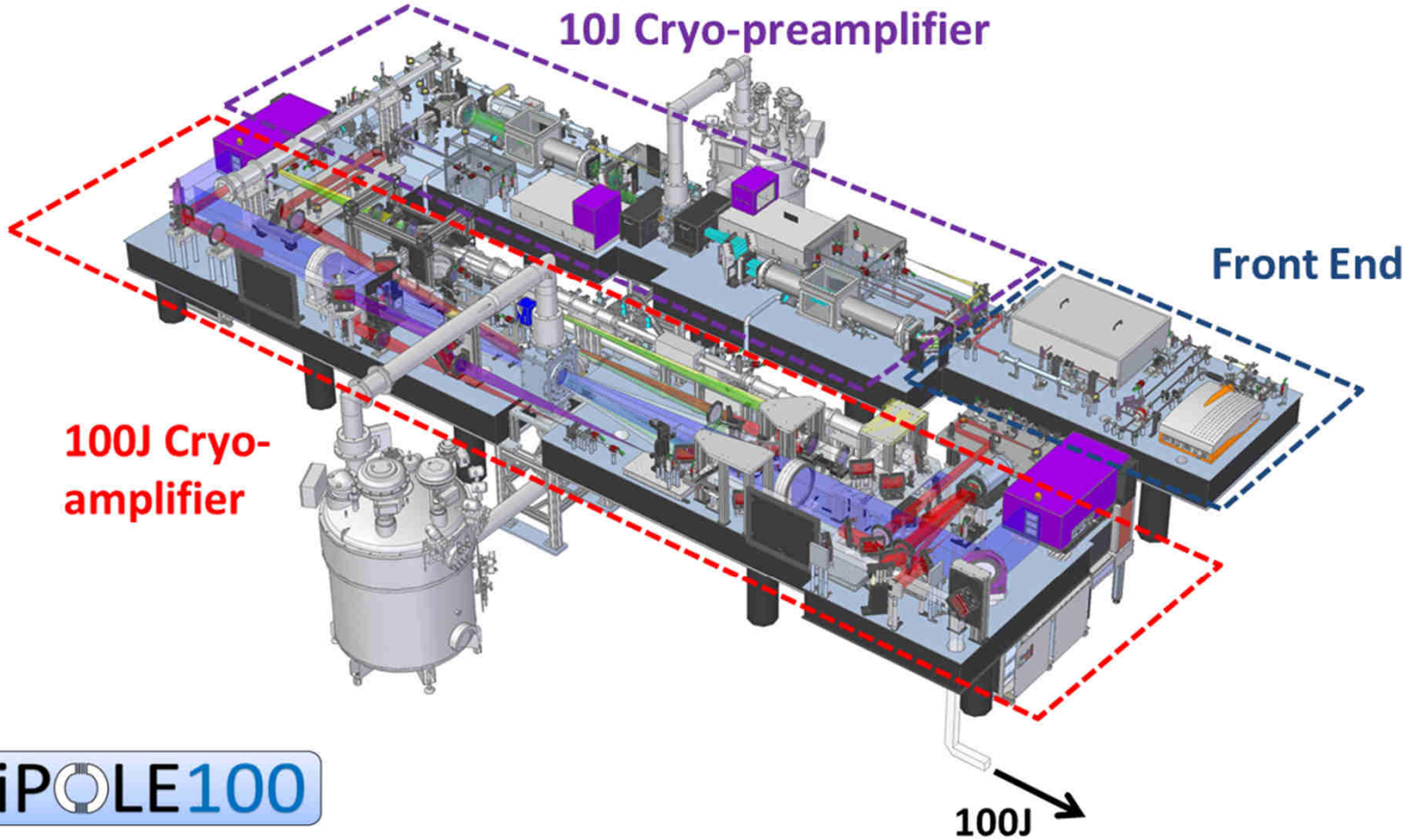
HiBEF

HE laser (HE-OL)

DiPOLE


HI laser
HE laser
Amplitude
DiPOLE100
HI beam transport
HED interaction area 1
HE beam transport
SASE 2 XFEL beamline

The DIPOLE-100X laser
- system layout -

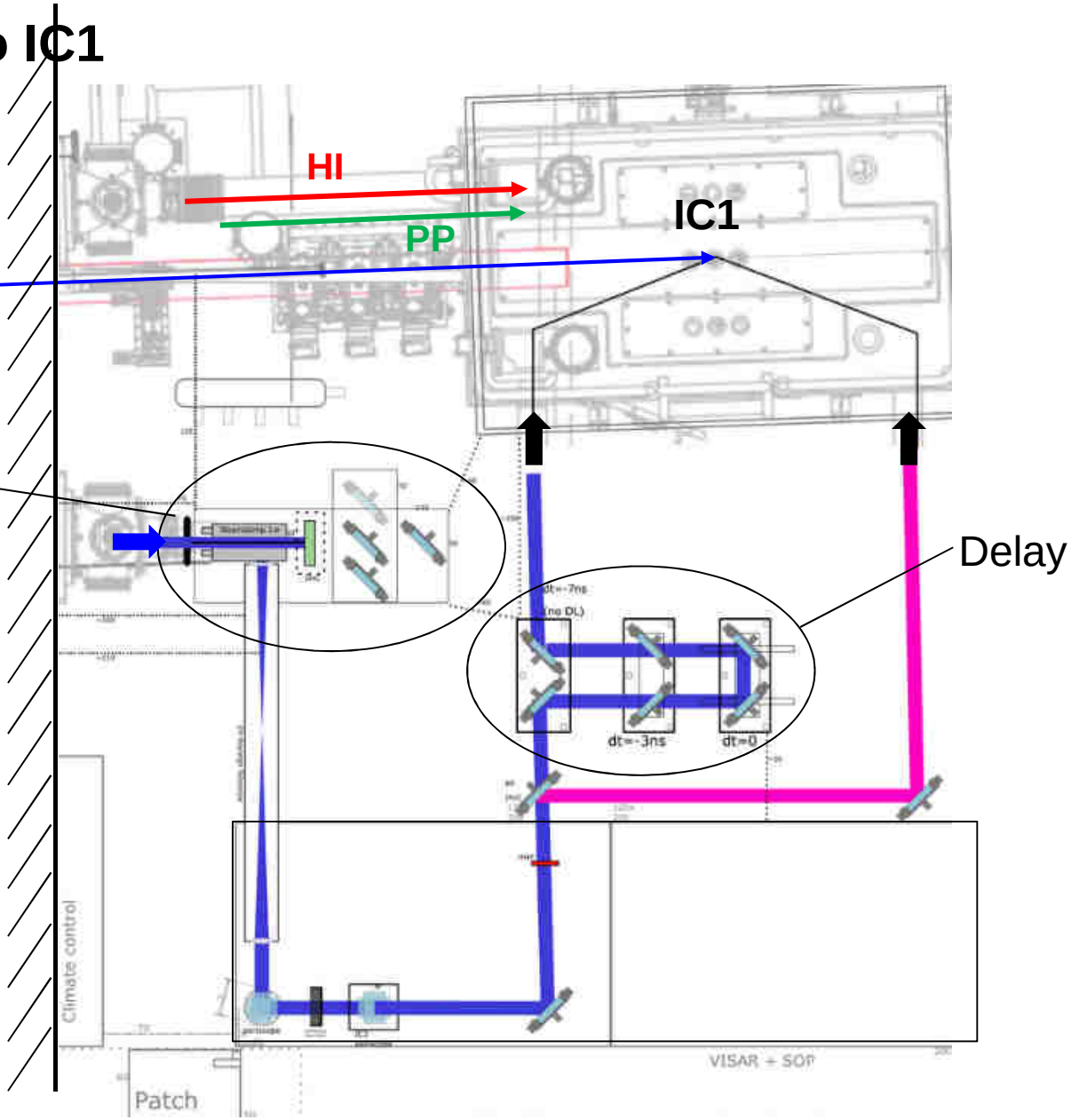


DiPOLE100

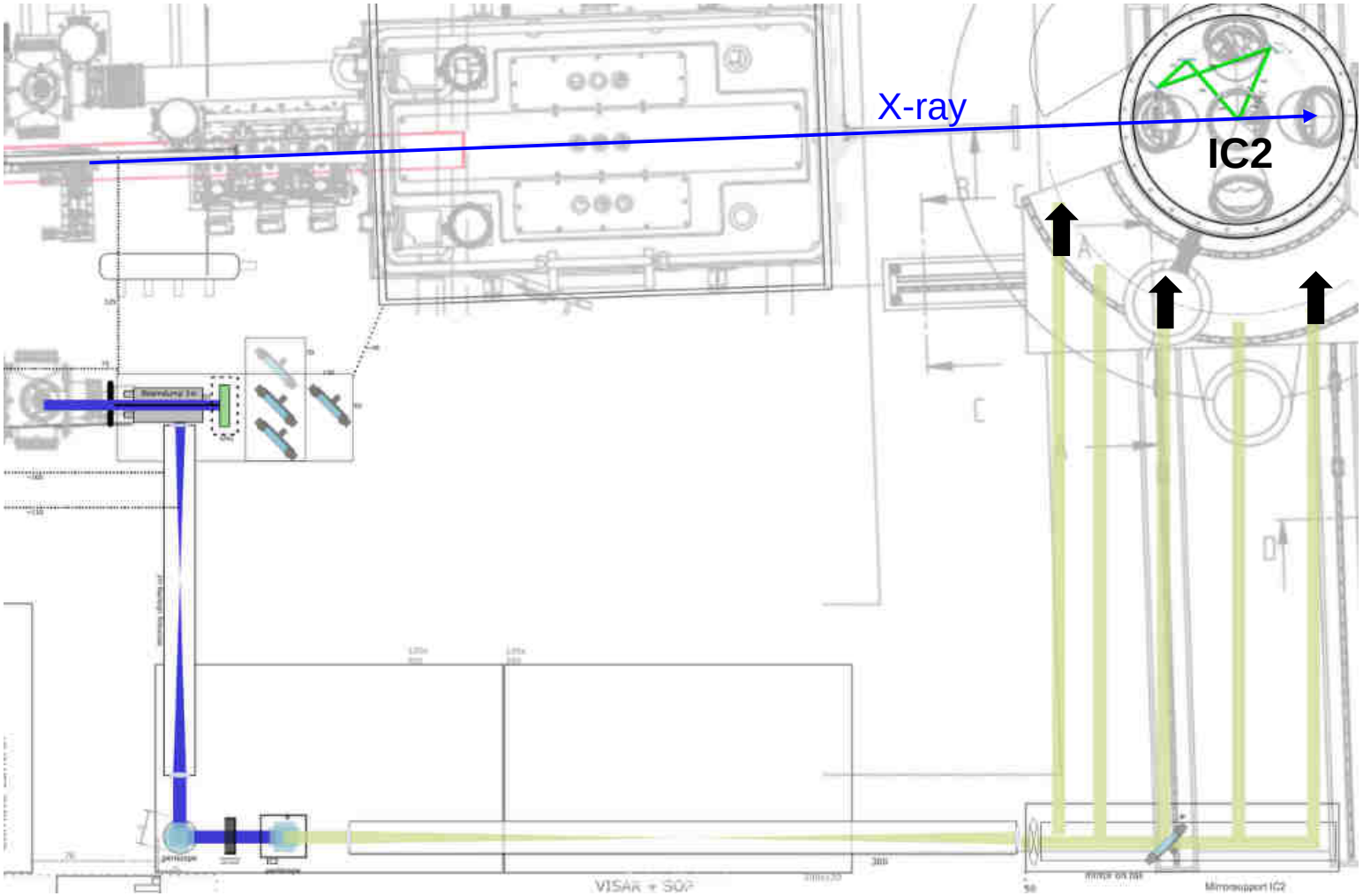
HE-OL transport to IC1

SHG, laser diagnostics

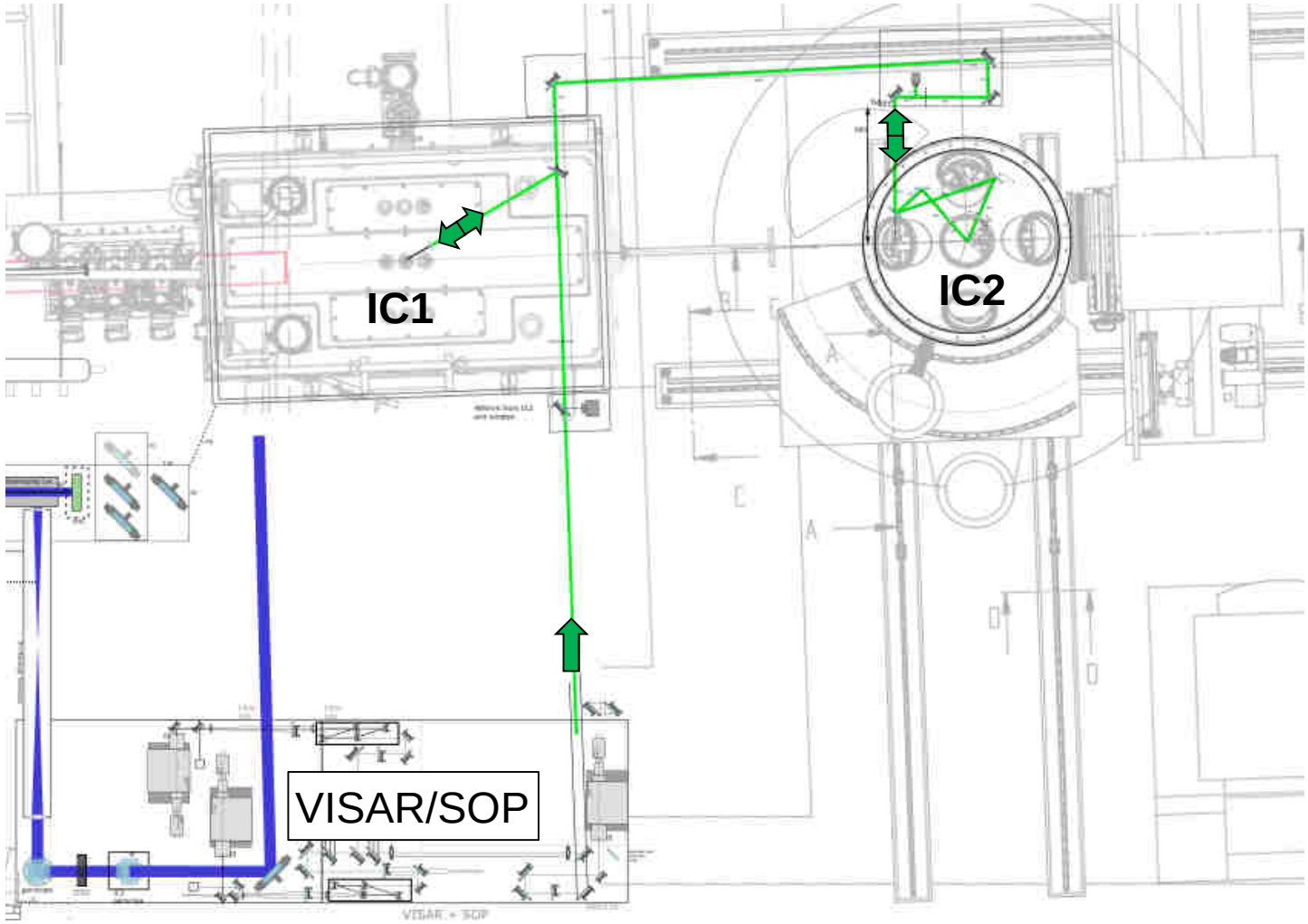
- Far & near field
- Spectrum
- Temporal profile
- Energy
- Wavefront



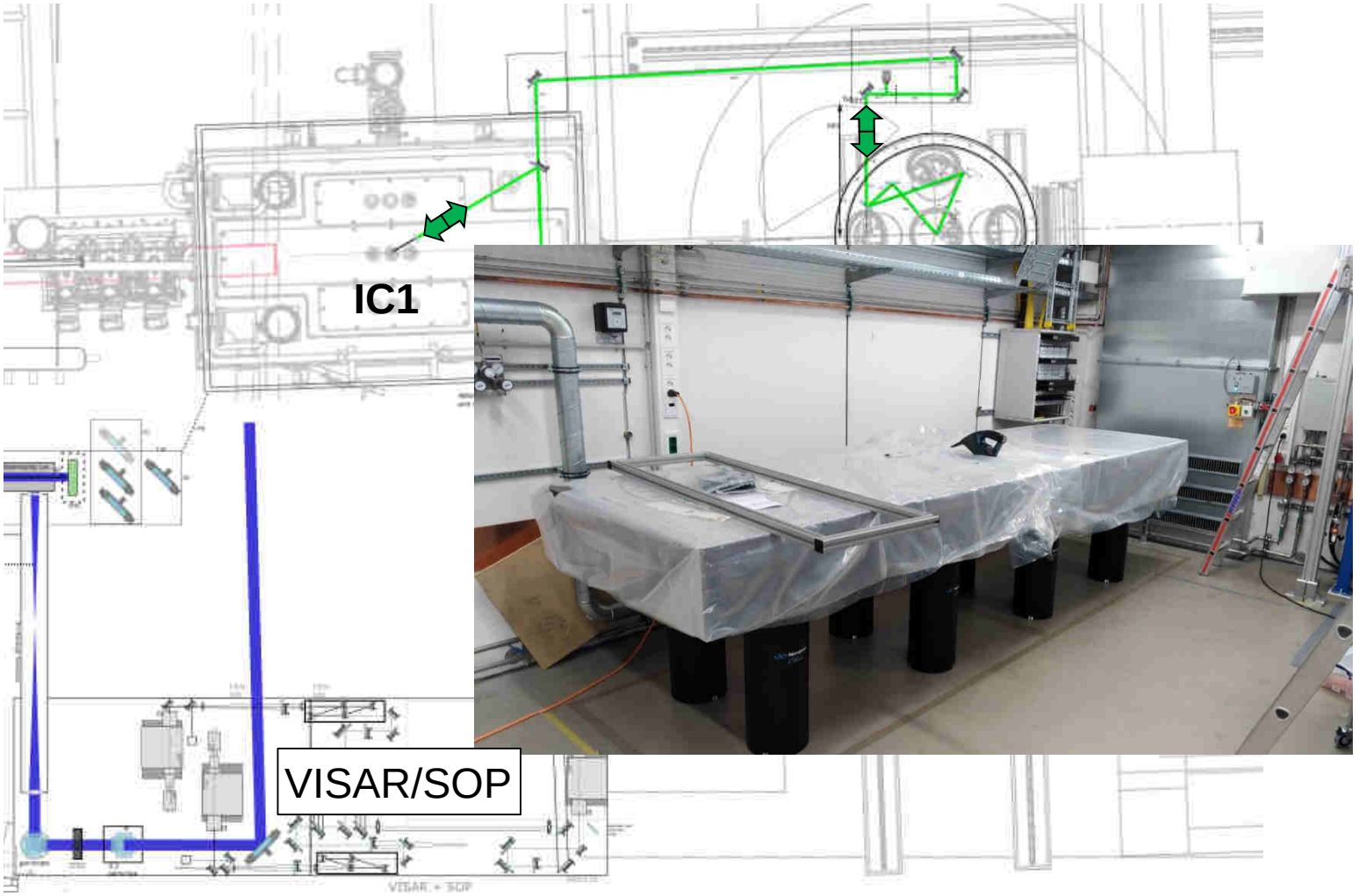
HE-OL transport to IC2



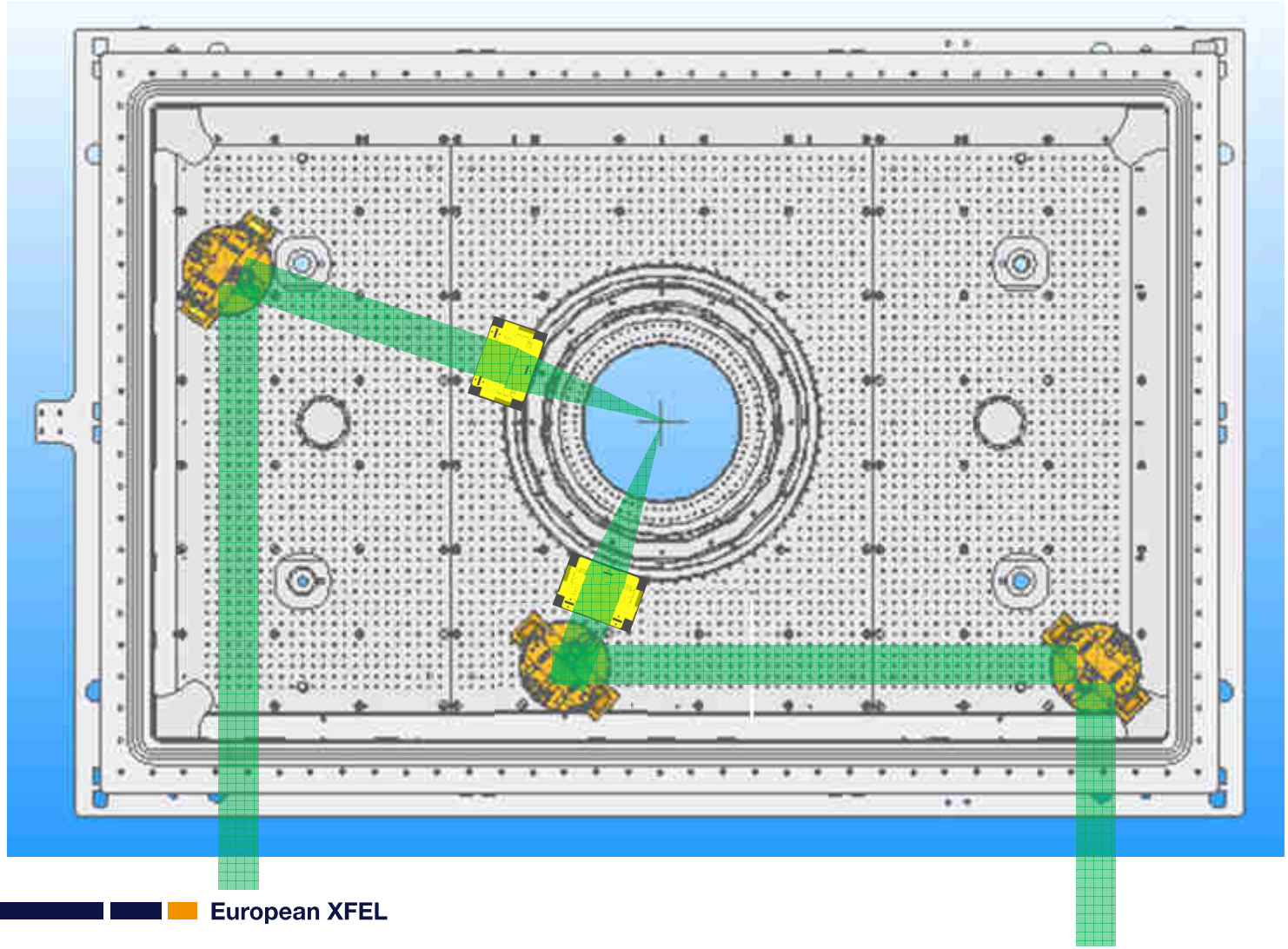
VISAR transport



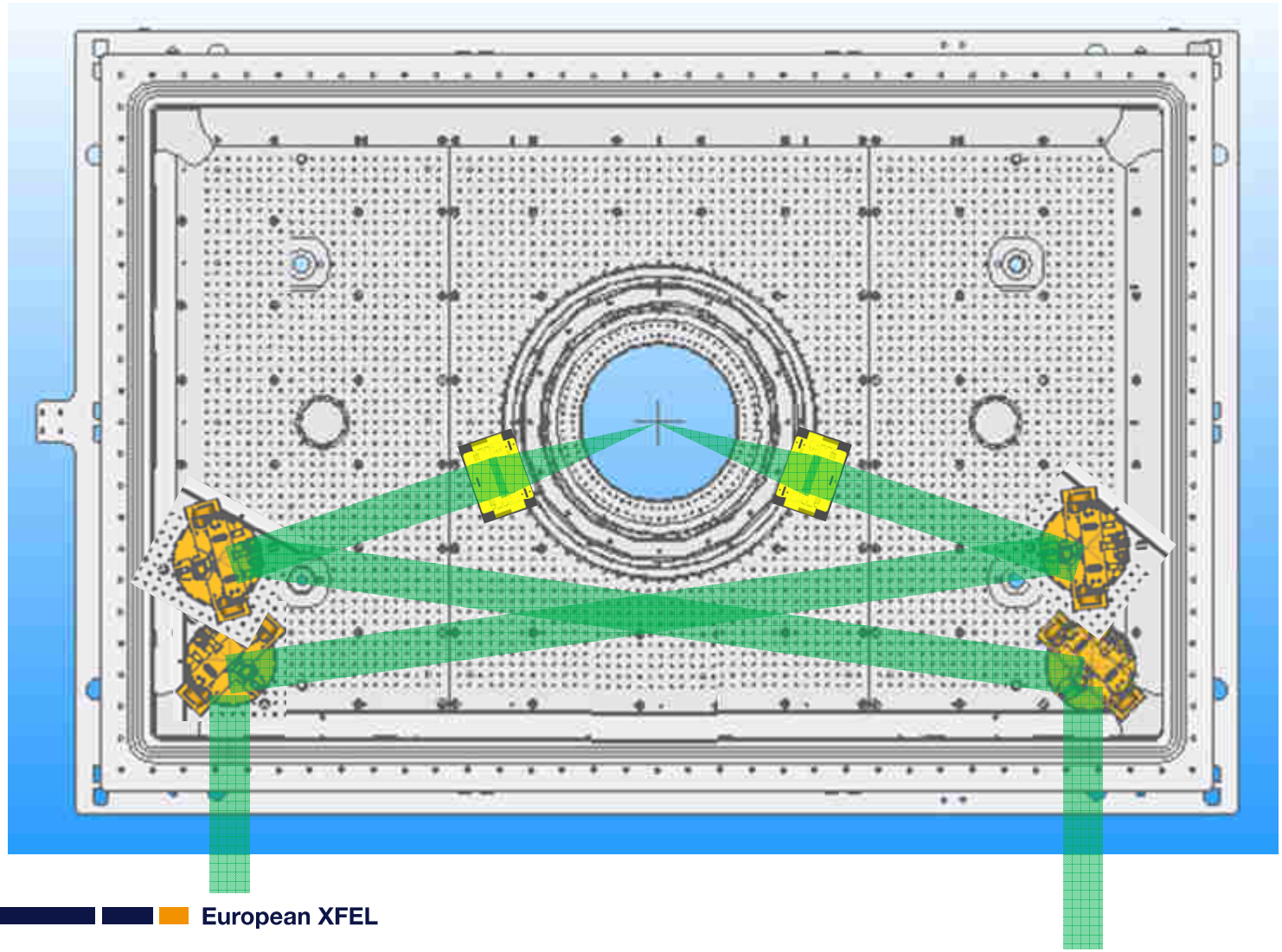
VISAR transport



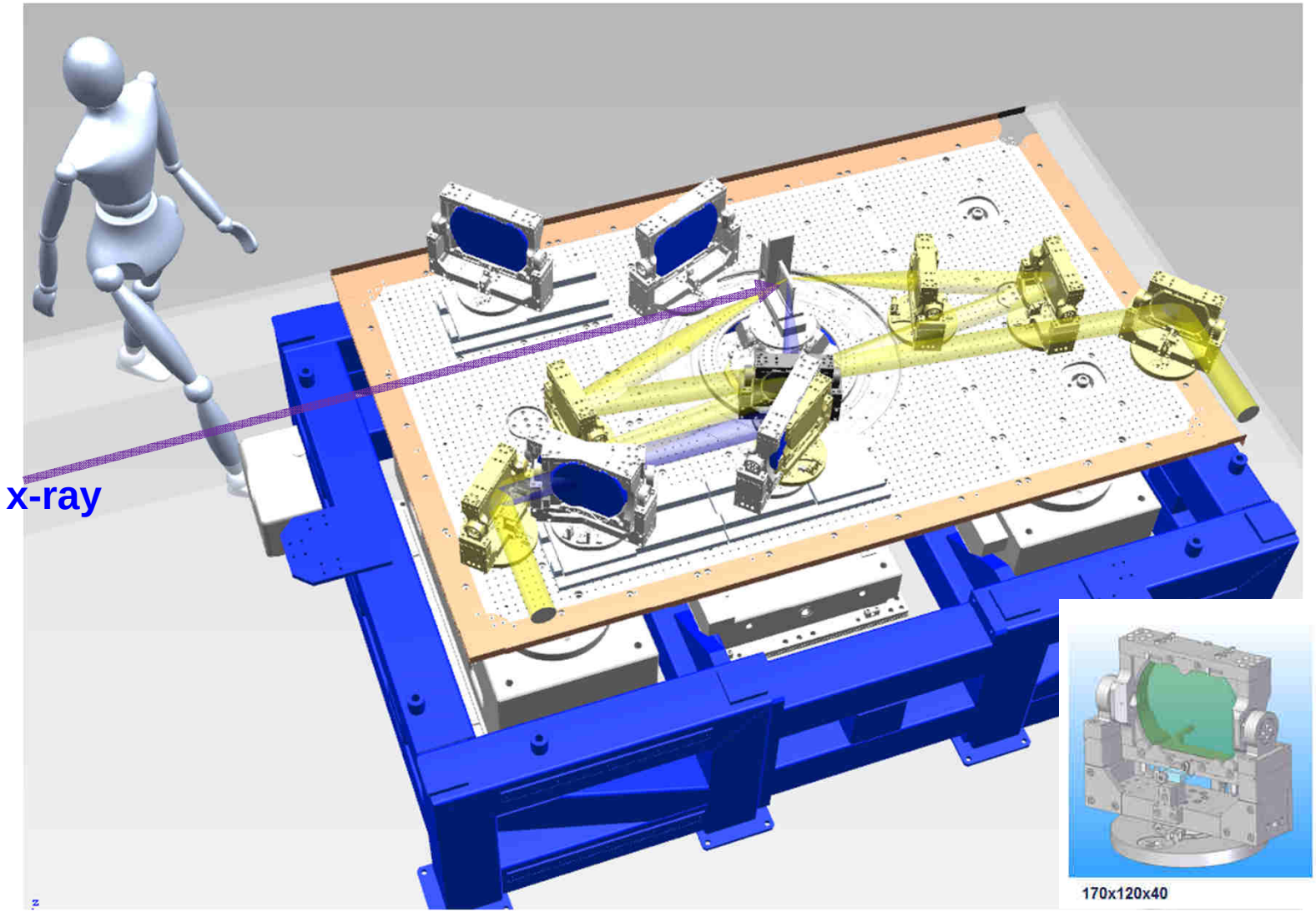
Inside IC1



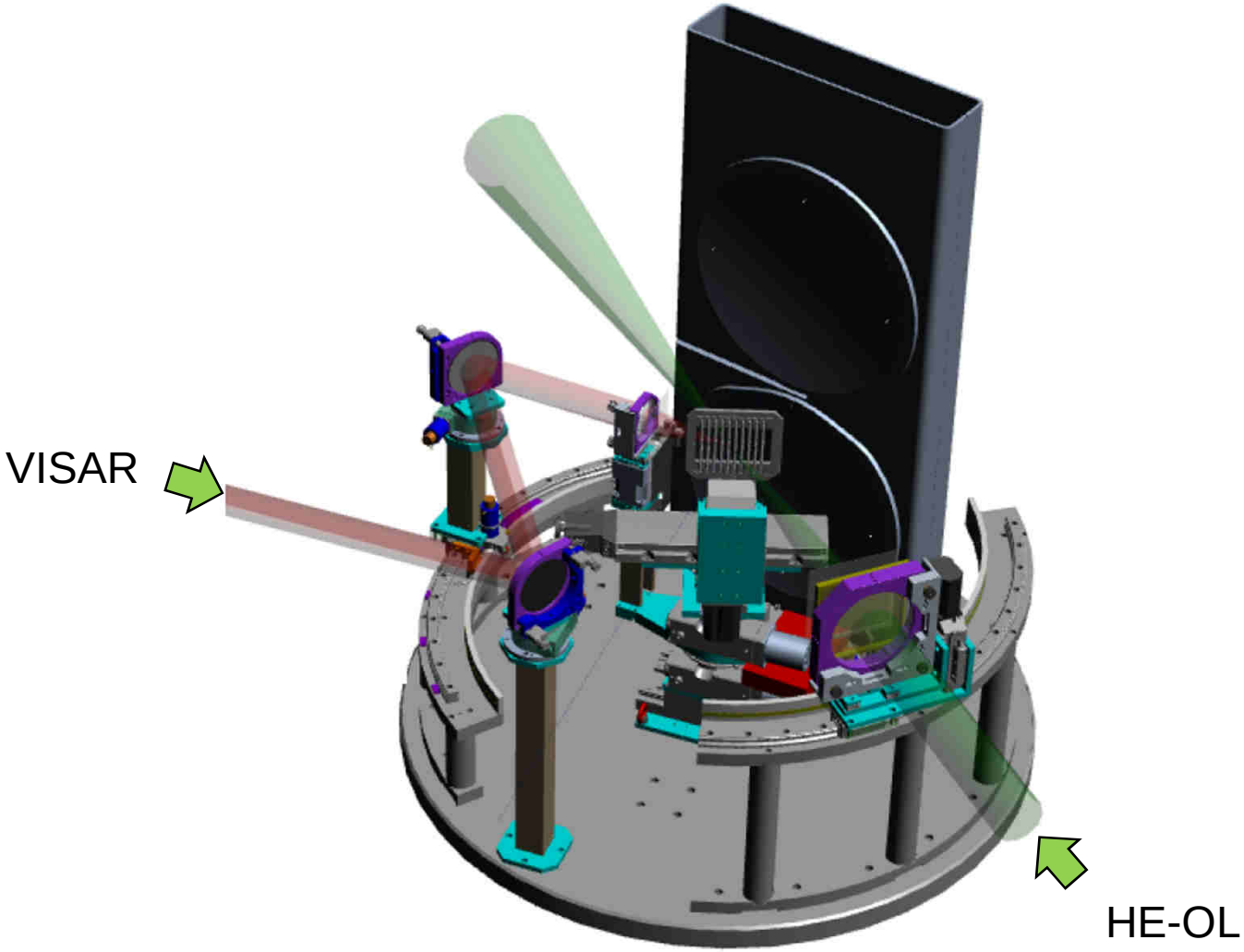
Inside IC1



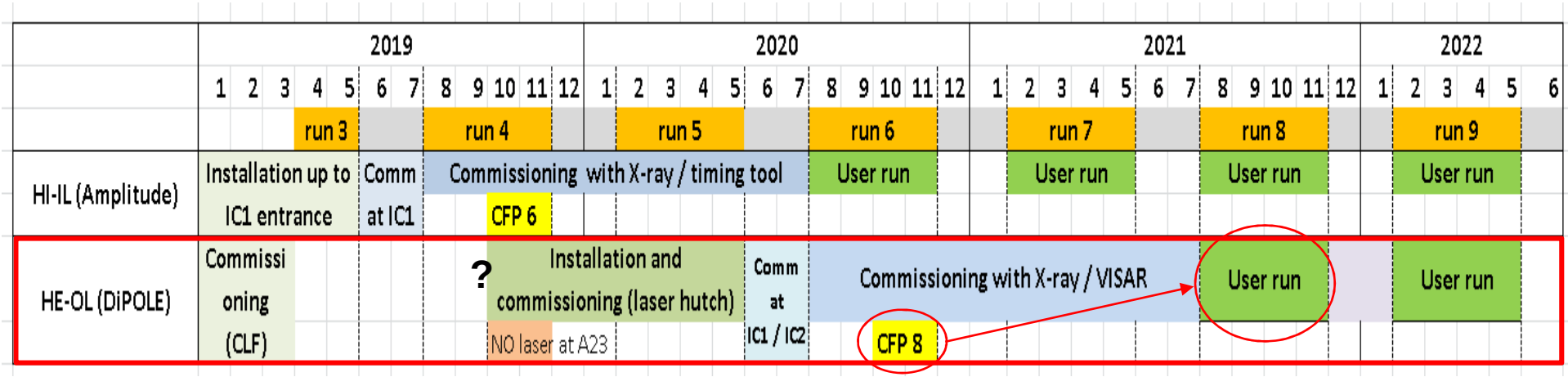
Example of HE-OL transport inside IC1



Inside IC2



HE-OL installation / commissioning schedule (best guess)



<u>Installation of HE-OL?</u>

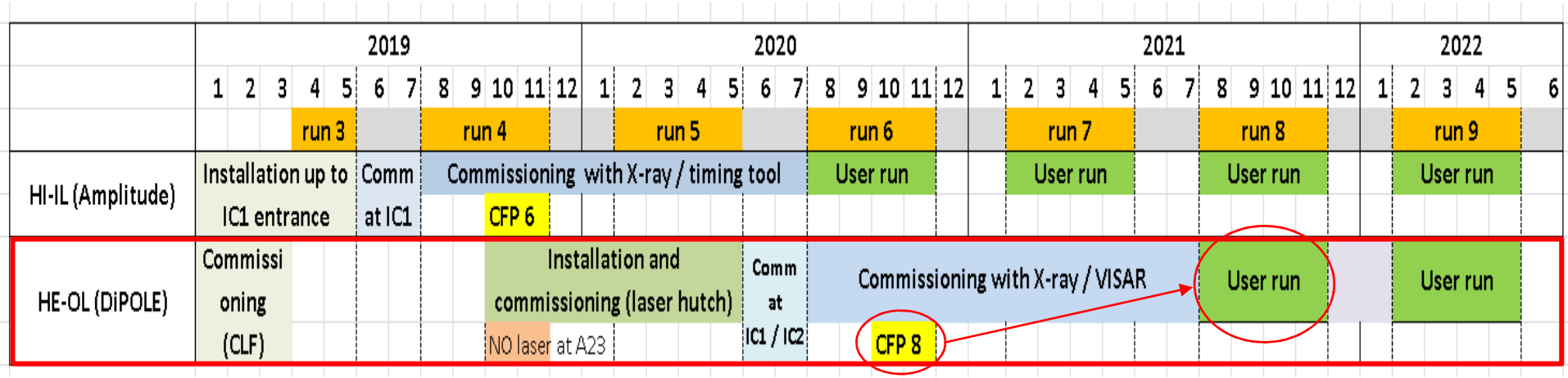
- Pending contract issue should be solved
- HI-OL commissioning shouldn't be heavily interrupted

➡ **Begin Oct. 2019 ?**

<u>Be ready to bring the beam to Exp hutch by summer shutdown in 2020</u>

- Commissioning at IC1, IC2.
- VISAR installation should start soon

HE installation / commissioning schedule (best guess)



<u>First user run with DiPOLE seems to be second half 2021 (CfP autumn 2020)</u>

- Precise organizing – in-parallel operation with HI-OL (man-power)
- First user workshop?

<u>Laser transport (in-air, IC1, IC2)</u>

- Design ☺
- Optics / optomechanics / stages 😐
  - Phase plate
  - Debris shield

<u>VISAR implementation ☹</u>

- Table installed

The joint HED and HIBEF team at European XFEL

Missing on picture:
V. Cerantola, C. Plückthun, J. Kaa, J-P. Schwinkendorf

Thank you

HiBEF laser team

T. Toncian
C. Bähtz
A. Berghäuser,
S. Di Dio Cafiso,
M. Hassan,
J. Hauser,
H. Höppner,
D. Möller,
A. Pelka
M. Toncian
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EuXFEL Laser Group

E. Brambrink
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G. Palmer
G. Priebe†
M. Lederer
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EuXFEL HED Group

T. Preston
J-P. Schwinkendorf
I. Thorpe
K. Sukharnikov
A. Schmidt
U. Zastrau
…

Summary

Made available to Users: