The Extreme Light Infrastructure

Joint Call for Users Webinar

The ELI ALPS Research Institute

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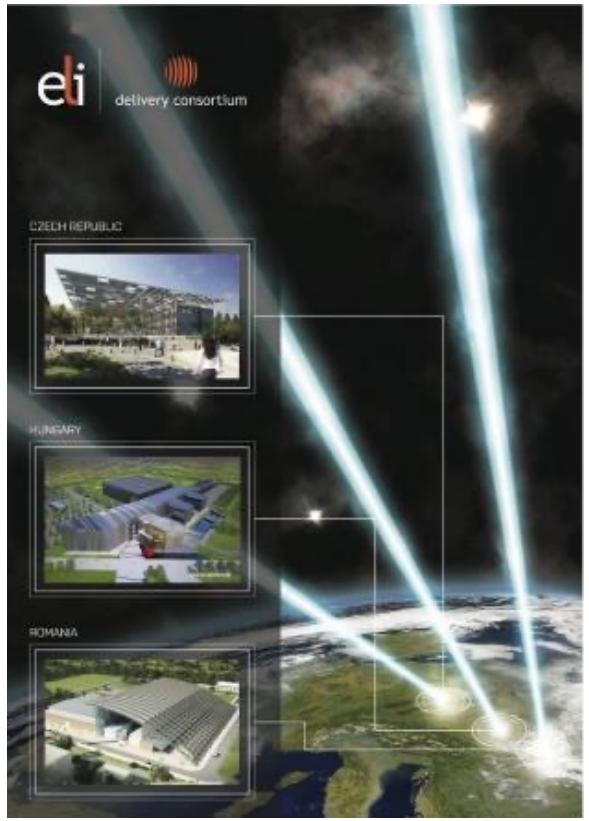
Chief Scientific Advisor, ELI-ALPS

18 July 2022

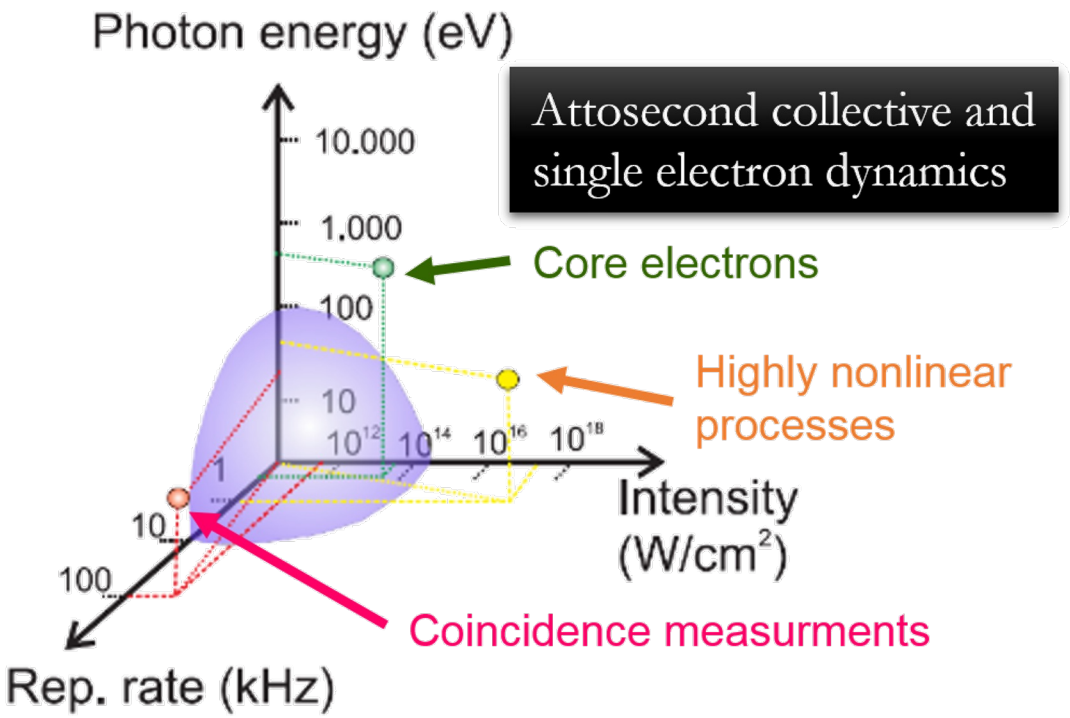
The ELI project: a distributed research infrastructure of the ESFRI roadmap

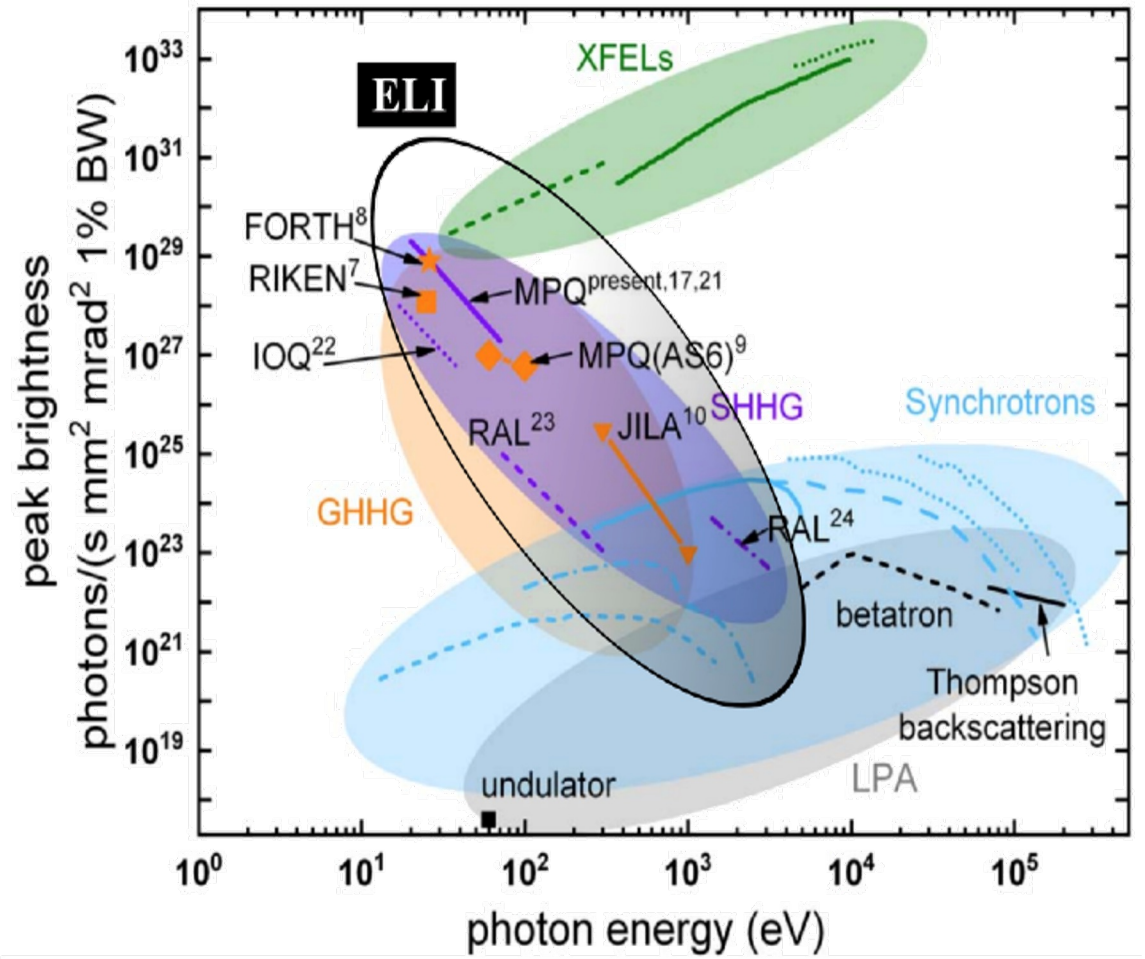
ELI:
To strengthen Europe's leading role in laser physics.
User facility for researchers of various disciplines.



3 complimentary pillars
Mission of ELI ALPS:
To provide advanced femtosecond and attosecond pulses, for temporal investigations of ultrafast dynamics in atoms, molecules, plasmas and solids.

Global complementarity ELI-ALPS





J. Electron Spectros. Relat. Phenomena **204**, 257 (2015)

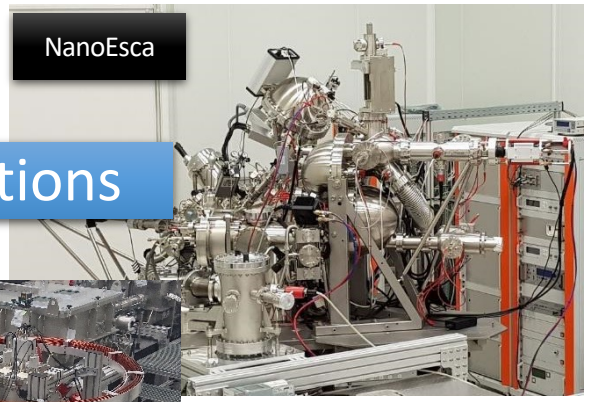
J Phys B **50**, 132002 (2017)

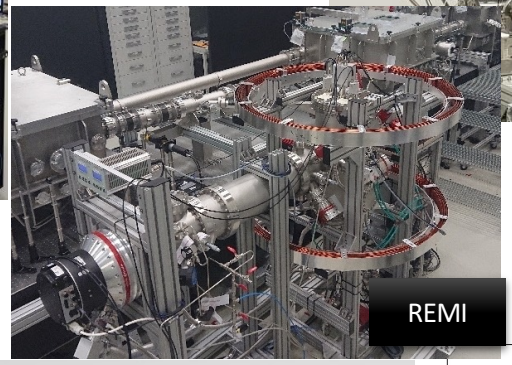
Optica **6**, 280-287 (2019)

Portfolio of research opportunities
Capacity, Capability and Uniqueness

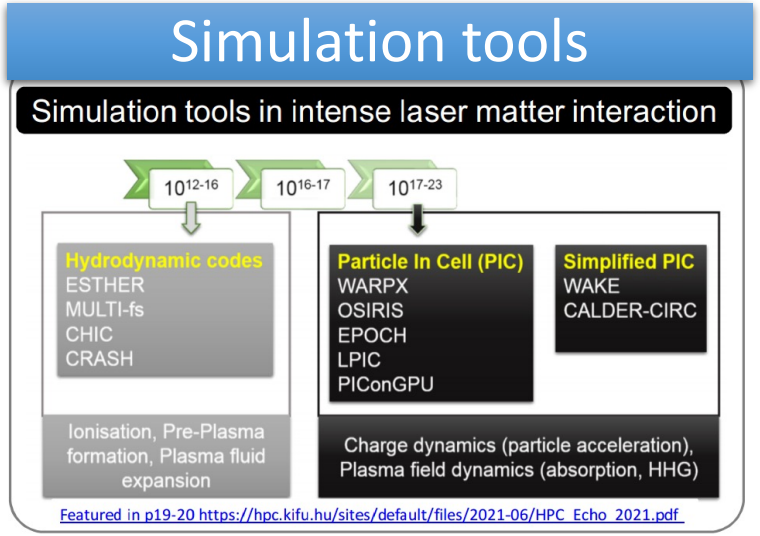
Lasers

Endstations



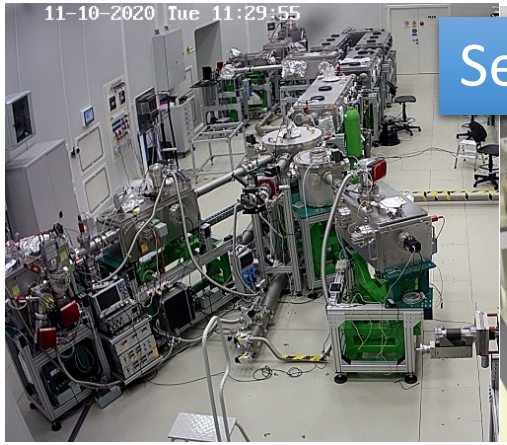


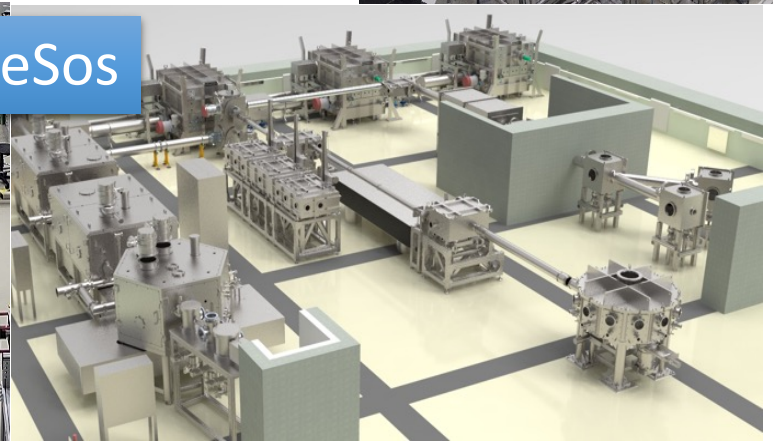
Simulation tools



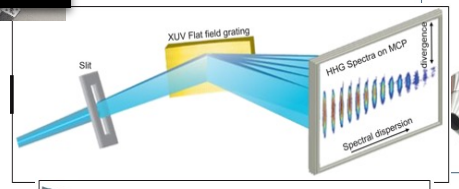
Featured in p19-20 https://hpc.kifu.hu/sites/default/files/2021-06/HPC_Echo_2021.pdf

SeSos

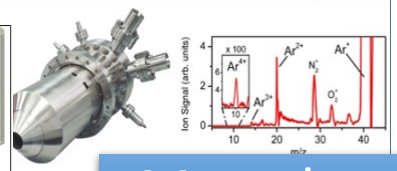




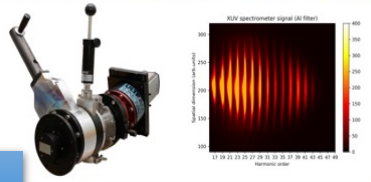
Metrology

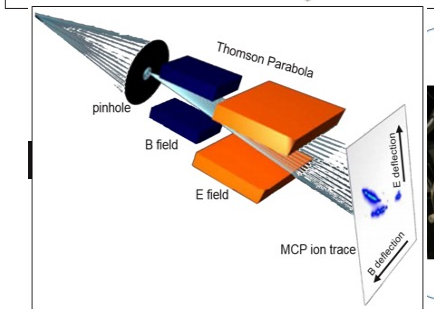


Electron/Ion TOF (5x + high resolution)

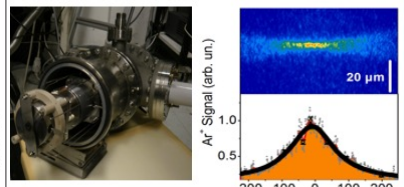


XUV/VUV Photon spectrometer (5x)

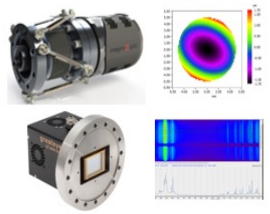




Ion Microscope (2x)



Beam diagnostics



XUV wavefront sensor

XUV CCD camera

ELI ALPS - Achievements to date

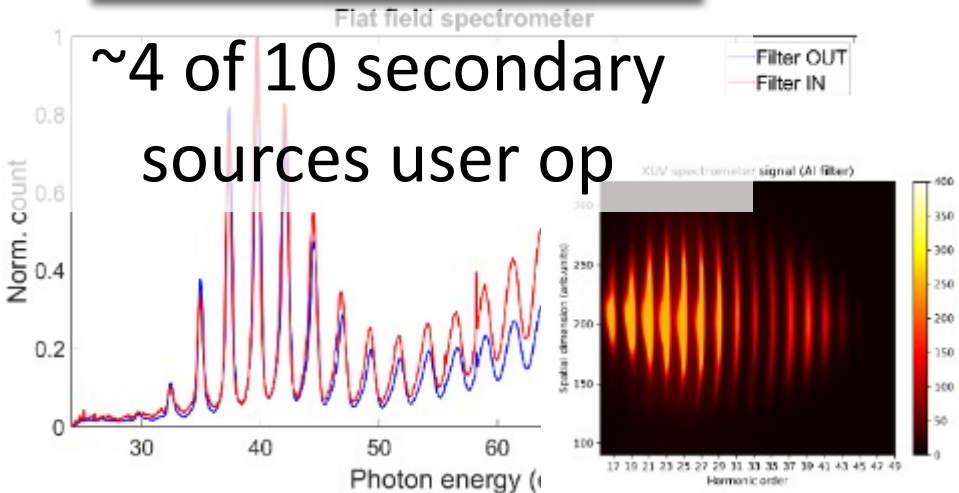
Laser systems commissioned

5 of 9 lasers
user operational

Experimental stations / labs

5 of 12 experimental
stations
user operational

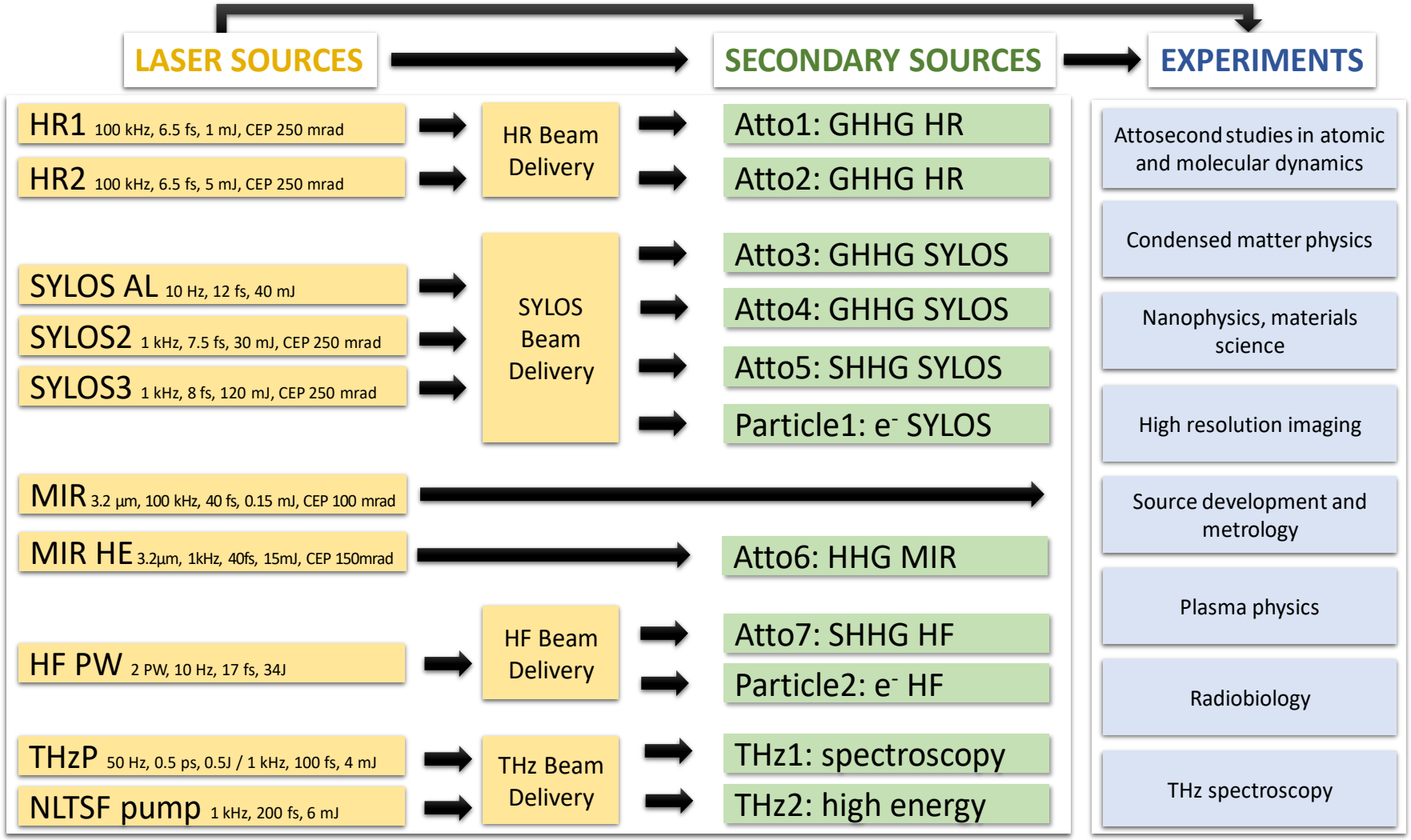
1st attosecond pulses



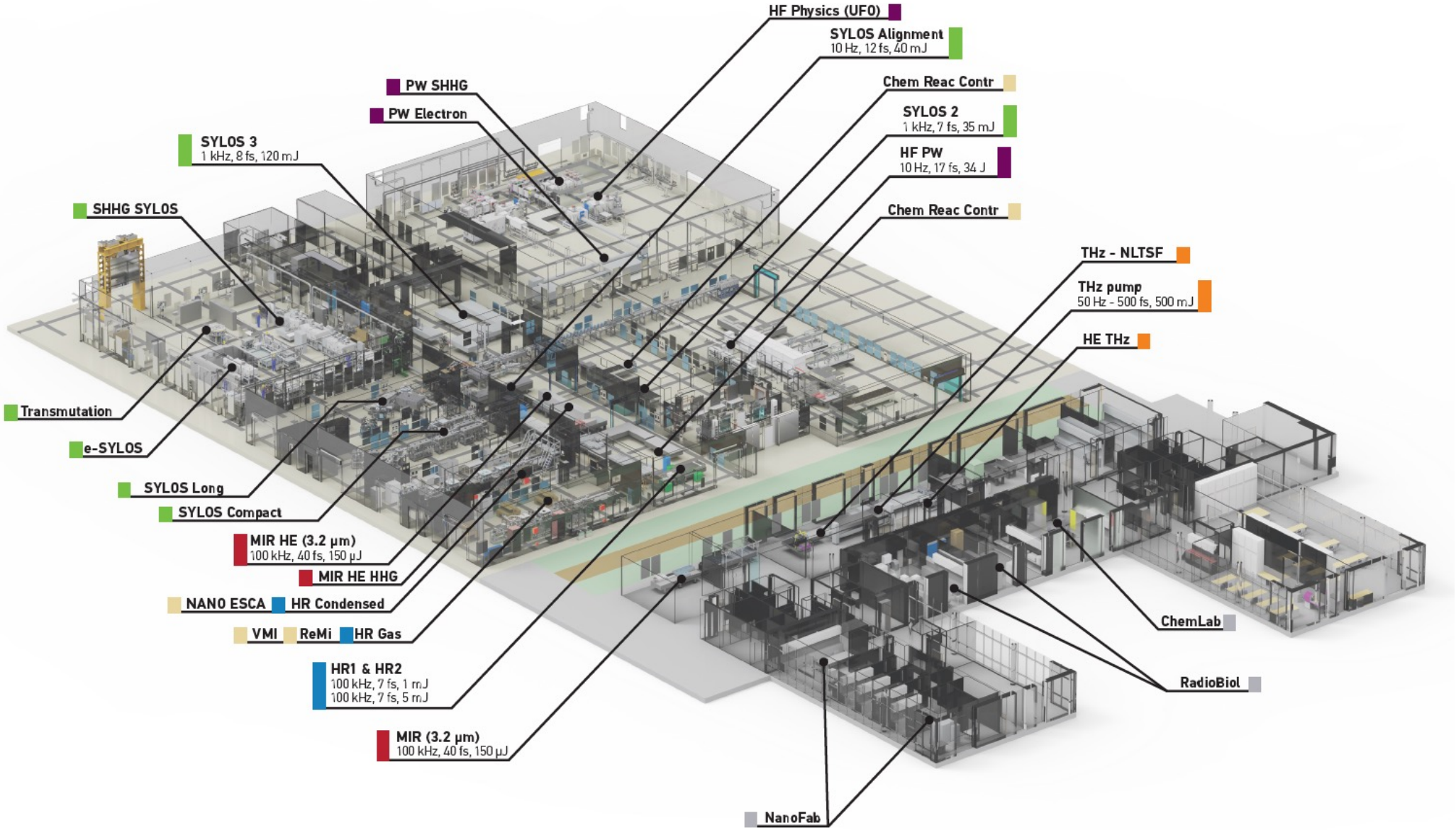
~4 of 10 secondary
sources user op

~40 completed
collaborative / user
campaigns
3000+ user hours

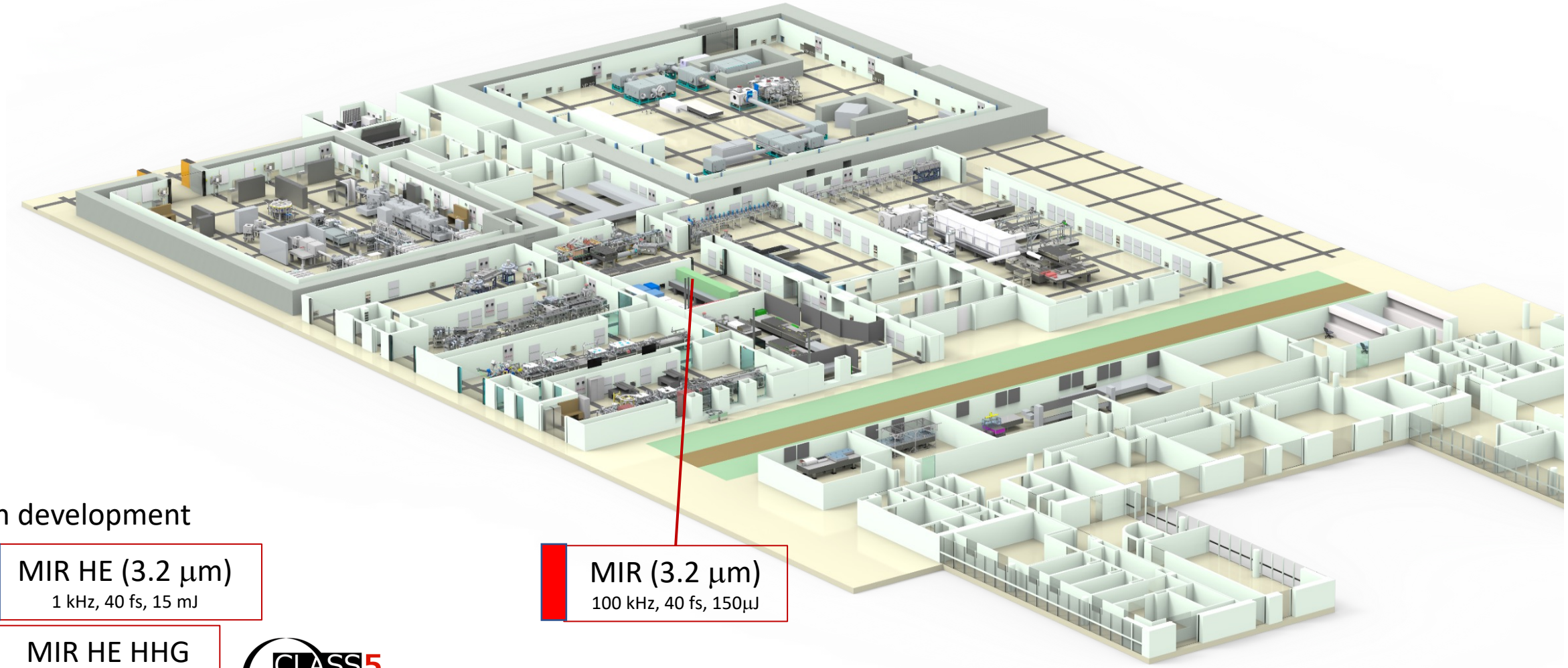
Research potential offered @ ELI ALPS



Facility overview



ELI-ERIC call instruments
The MIR activity ~ 3mm



in development

MIR HE (3.2 μm)
1 kHz, 40 fs, 15 mJ

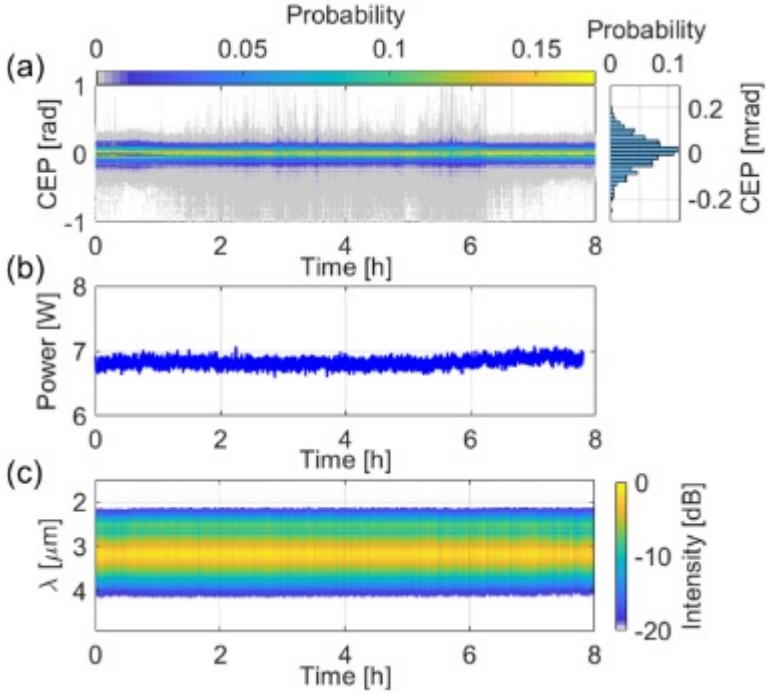
MIR HE HHG

MIR (3.2 μm)
100 kHz, 40 fs, 150μJ

Status of the MIR laser

user ready

14 user campaigns

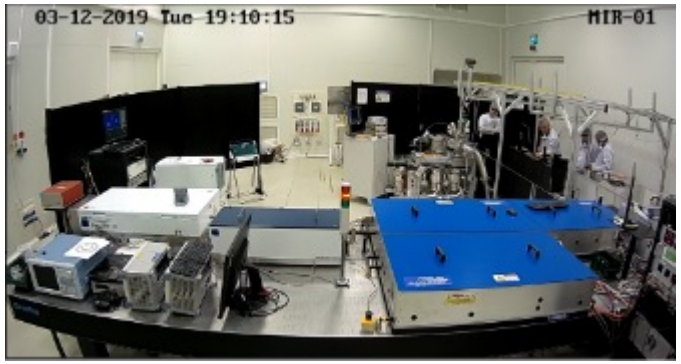


@100 kHz, active feedback loop, 82 mrad RMS

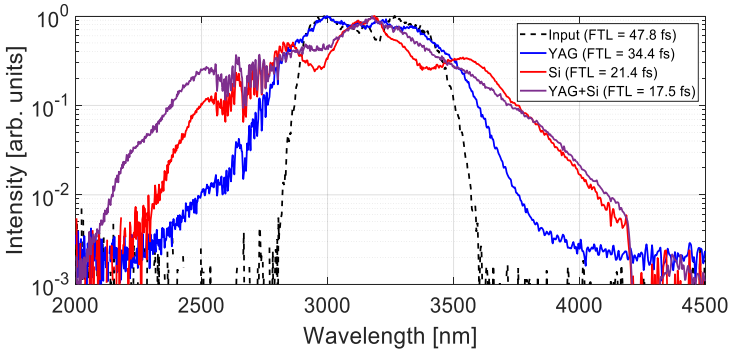
95% of points within [-150, +150]

0.9 % power stability

2.4 % pulse-to-pulse E stability



Spectral broadening in cystal pairs
(YAG & Si, BaF2 & Si)

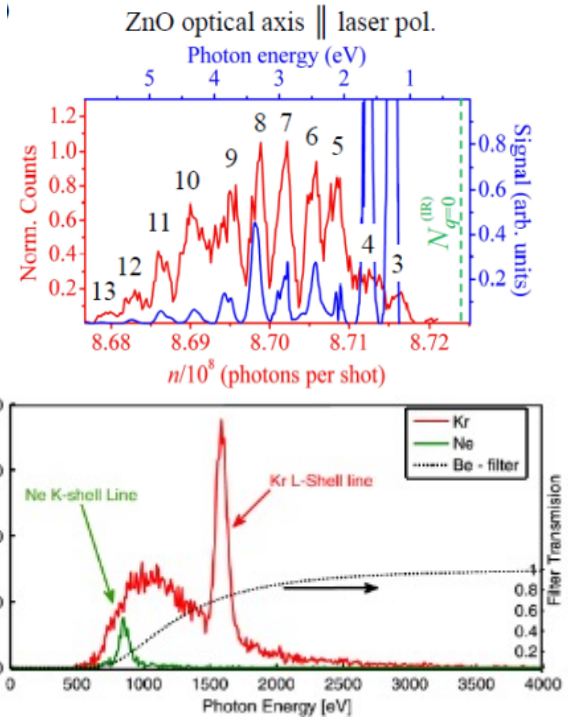


INPUT

11W, 110 μJ, 50 fs

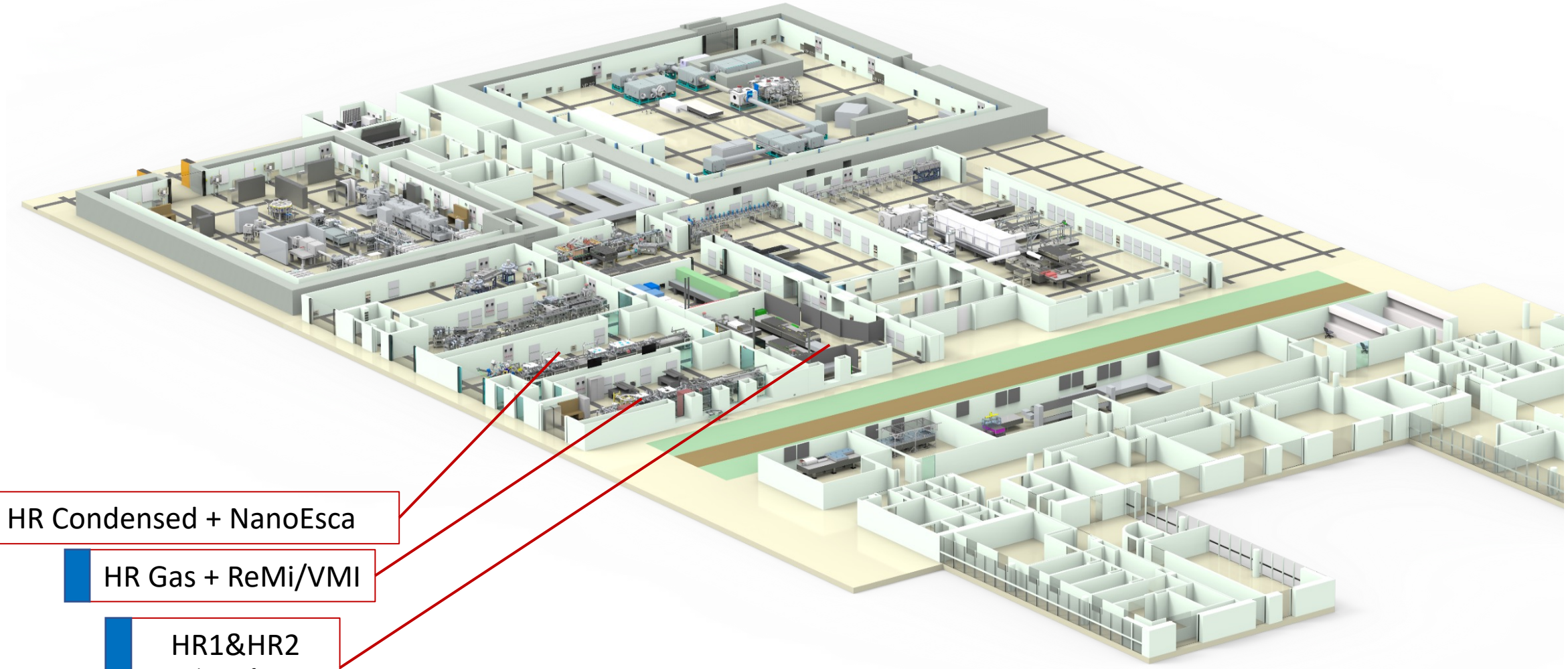
OUTPUT

88 μJ, (17.5 fs) 1.9 o.c.@ 3 μm



	Parameters	Status	Operation due date
MIR	*100 kHz, <40 fs, 0.15 mJ, CEP* *100 kHz, 17.5 fs, 88 μJ, CEP*	*Operational*	*since October 2017*

ELI-ERIC call instruments
The HR activity 100 kHz



HR Condensed + NanoEsca

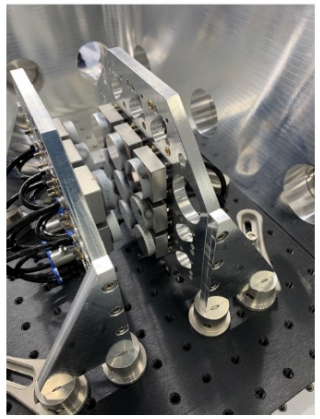
HR Gas + ReMi/VMI

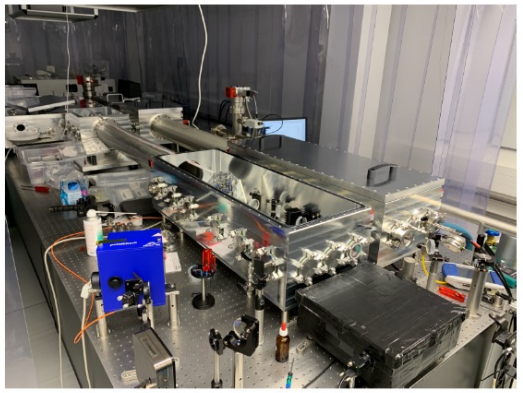
HR1&HR2
100 kHz, 7 fs, 1 mJ
100 kHz, 7 fs, 5 mJ

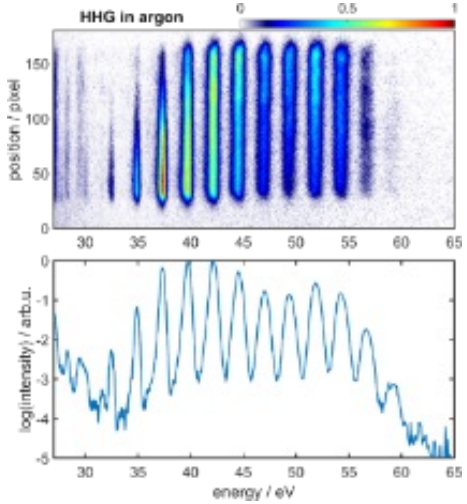
Status of the HR laser

- fiber laser technology
- double MPC concept for postcompression<7fs

HR1: user ready
7 user campaigns





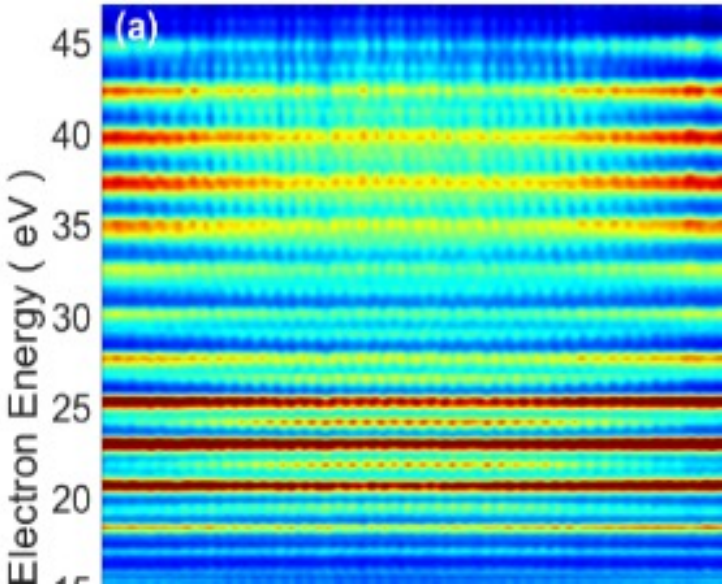


	Parameters	Status	User readiness
HR1	*100 kHz, 40 fs, 1.5 mJ* *100 kHz, <7 fs, 1 mJ, CEP*	*Operational*	*since Dec 2017* *Aug 2021*
HR2	100 kHz, <6 fs, 5 mJ, CEP	In development	by Q4 2022

Status of the HR GHHG Gas beamline (LTA-4)

user ready

- **XUV-IR pump-probe** studies on **gaseous targets** at **100 kHz**
- diagnostics for the temporal, spectral and spatial characterization of the XUV pulses
- **flexible reconfiguration** according to user needs (target area between CH04 nd CH05)



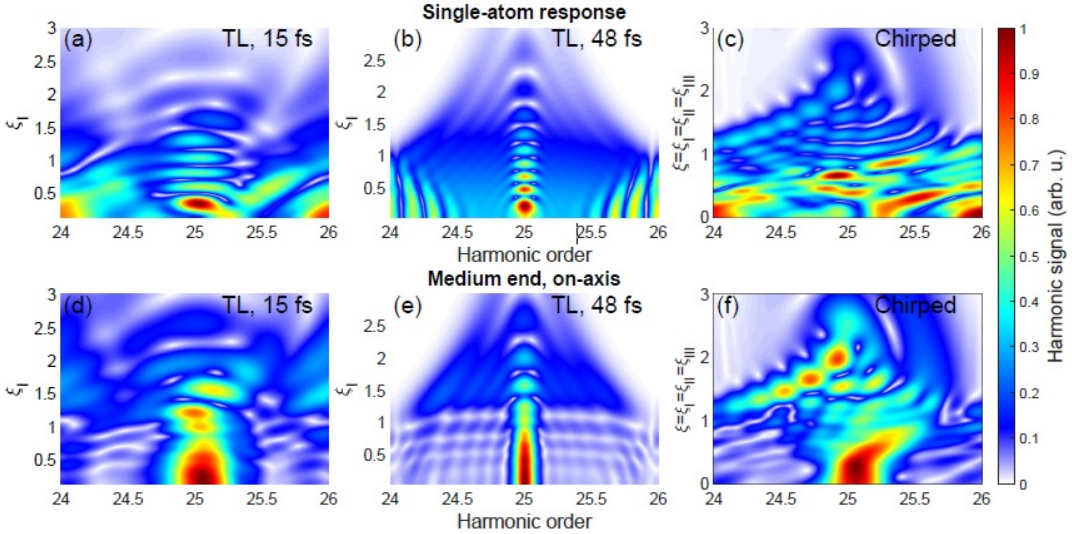
~166 as,
~150 pJ generated,
~50 pJ on target
@ 100 kHz

P. Ye *et al.*, J. Phys. B **53,** 154004 (2020)

P. Ye *et al.*, *submitted to Ultrafast Science* (2021)

CNR IFN Istituto di Fotonica e Nanotecnologie

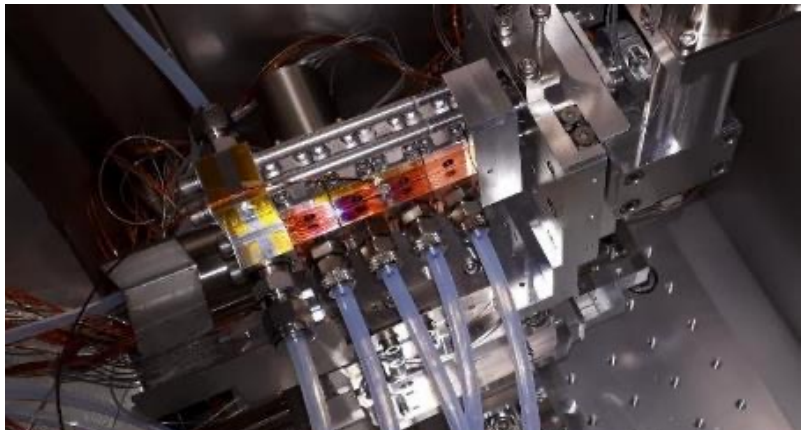
Quantum path interferences with chirped laser pulses

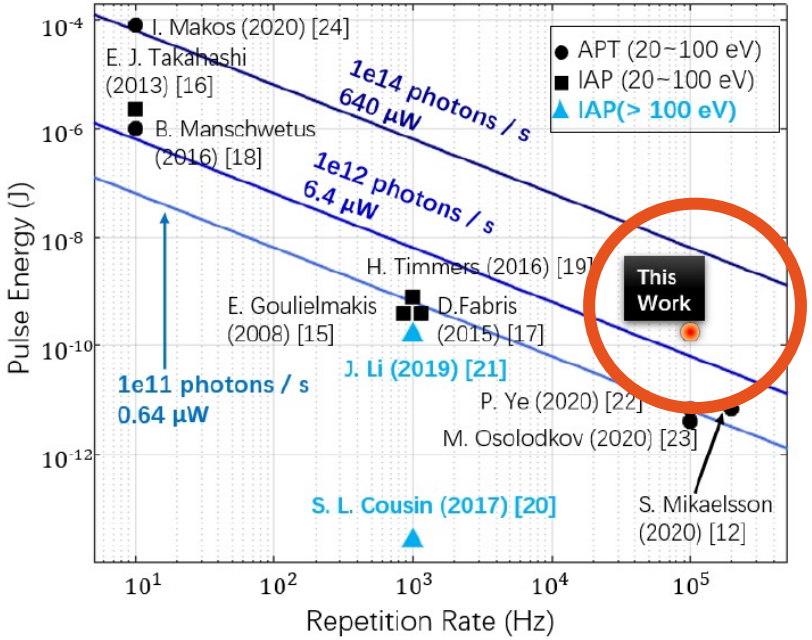


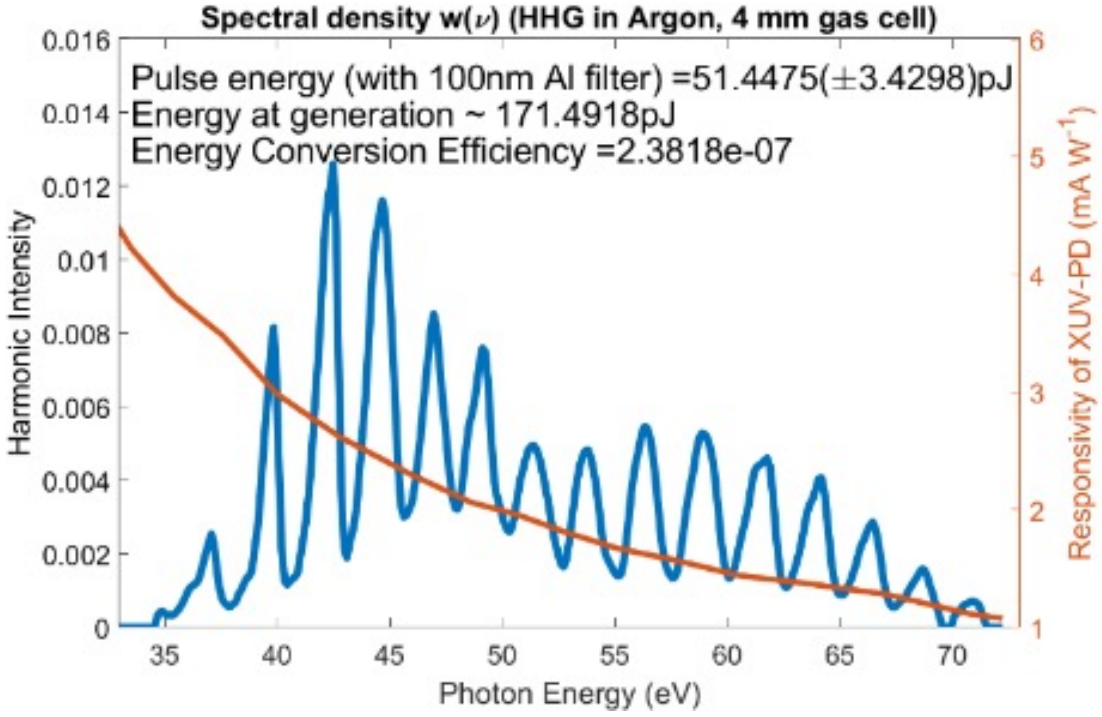
Results of HR GHHG Gas beamline (LTA-4)

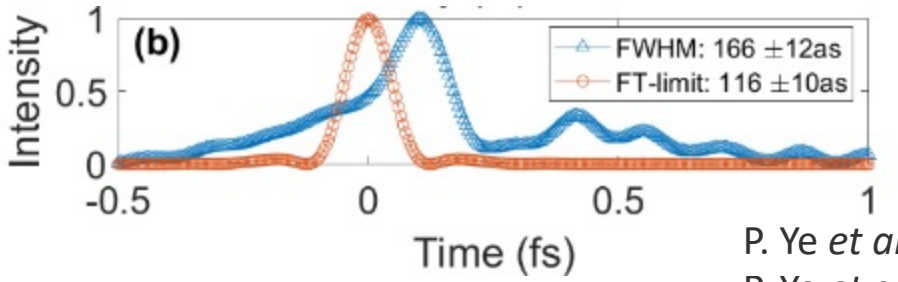
user ready

specially designed, cooled static HHG cell









~166 as,
~150 pJ generated,
~50 pJ on target
@ 100 kHz

Record flux

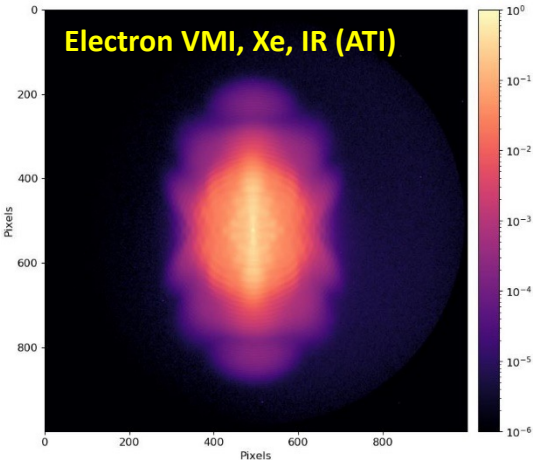
P. Ye *et al.*, J. Phys. B **53,** 154004 (2020)
P. Ye *et al.*, *submitted to Ultrafast Science* (2021)

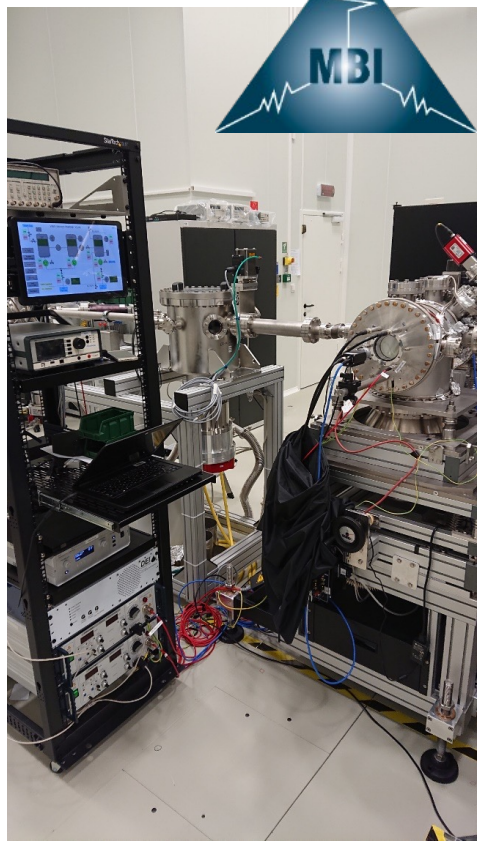
Experimental stations for gas phase studies

VMI-ES

user ready
mobile

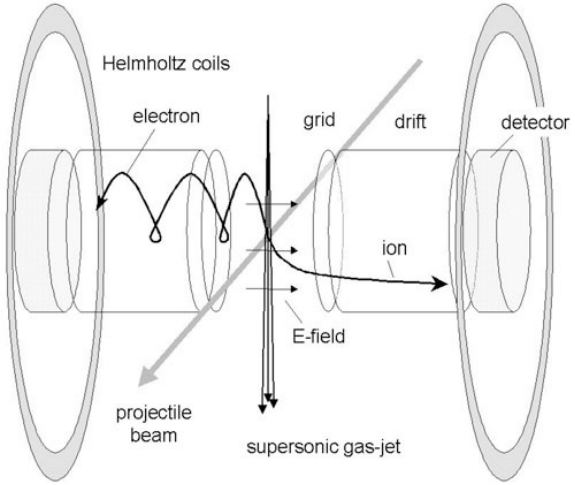
to obtain energy- and angle resolved information on ions and electrons resulting from the photoionization or photofragmentation of atoms, molecules or nanoparticles

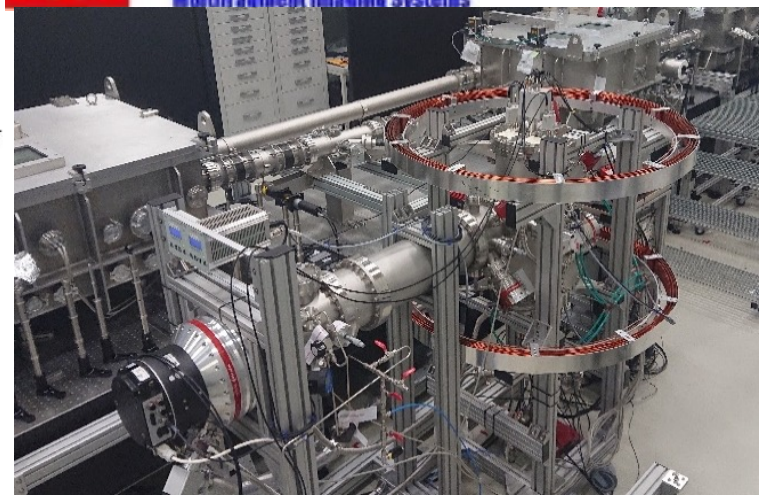




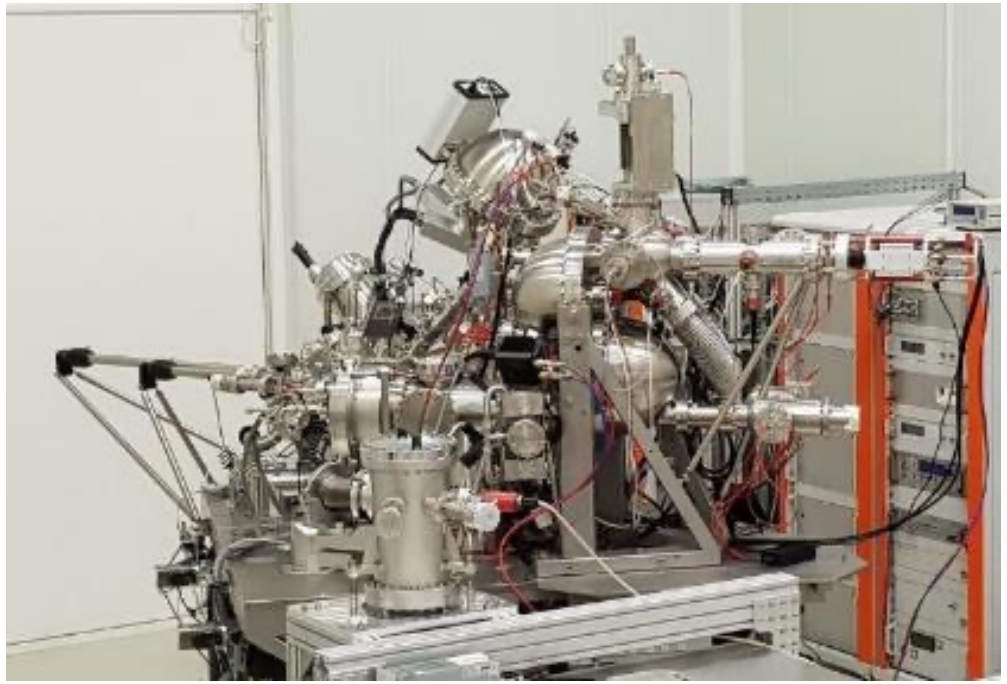
ReMi / Coltrims

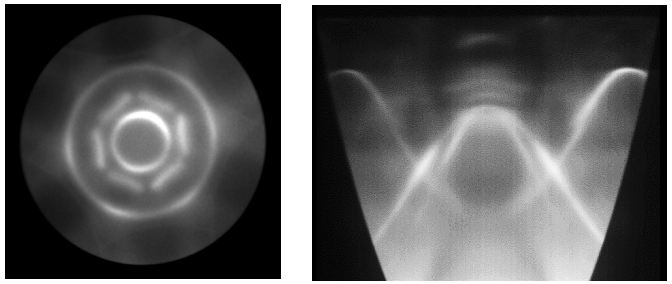
Kinematically complete experimental study of ion and electron fragments detected in coincidence





The NanoESCA end-station dedicated for condensed phase and surface dynamics



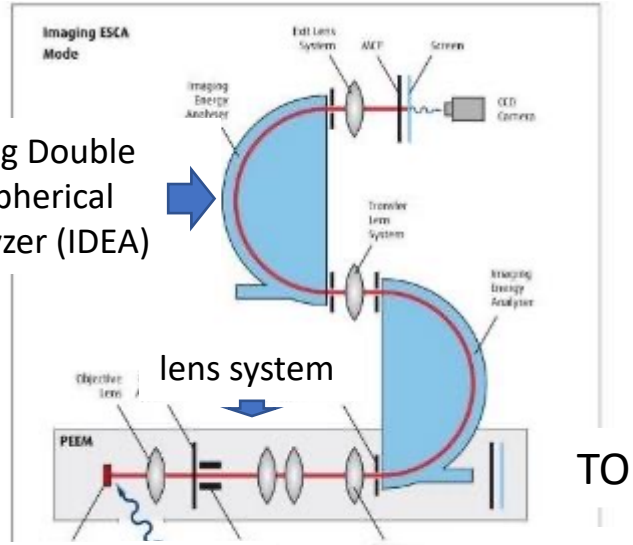


66 μm

Spin domains on an iron plate
(recorded at ELI w Hg lamp

user ready

2 user campaigns

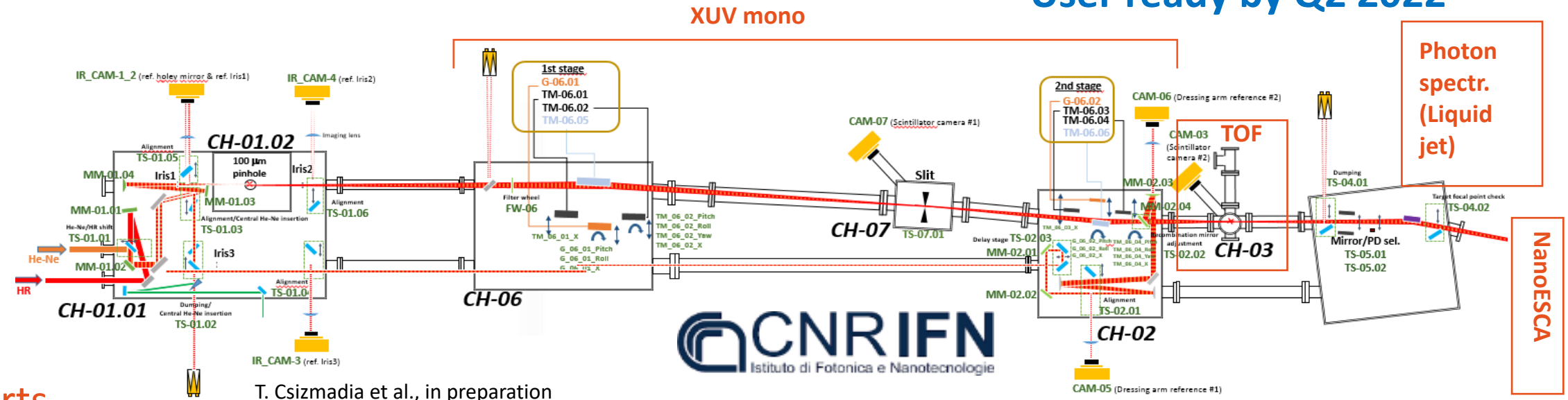


Core capabilities, at 100 kHz XUV – IR / 70 MHz fs CEP oscillator:

- Photoemission Electron Microscopy (PEEM) mode: laterally resolved microscopy of the sample surface with time resolution
- Imaging Photoelectron Spectroscopy mode: lateral, time and energy resolution
- Momentum microscopy: imaging of the momentum space, time and energy resolution
- With a state-of-the-art Au/Ir(100) imaging spin filter (spin selective electron detection)

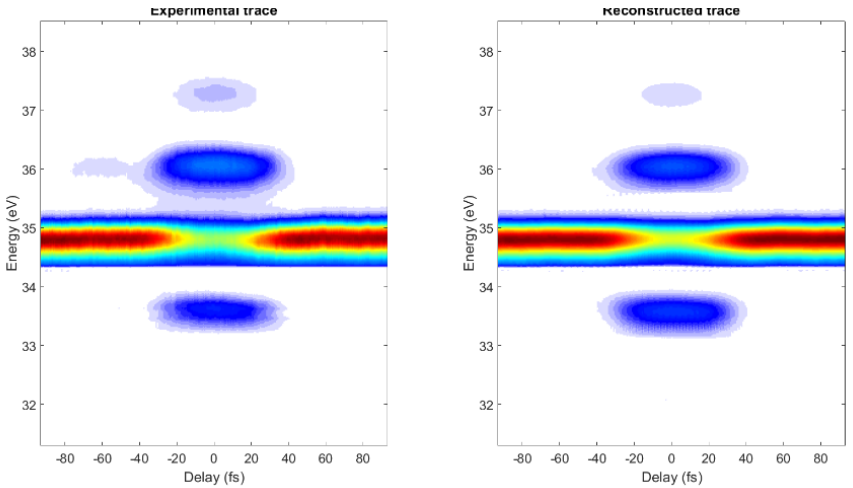
HR GHHG Cond beamline + XUV mono (LTA3)

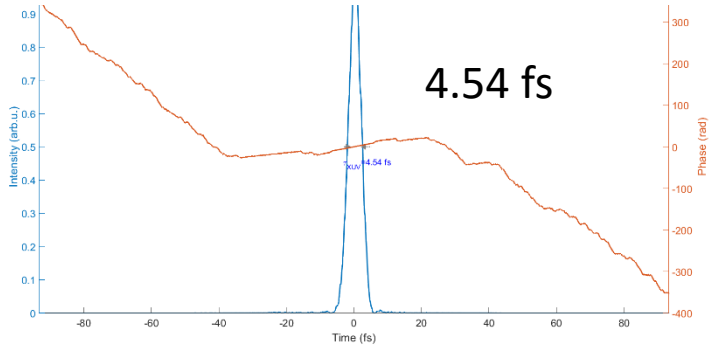
User ready by Q2 2022



T. Csizmadia et al., in preparation

Supports NanoESCA + liquid-jet end-station with XUV-IR pump-probe capabilities





Monochromatized XUV pulses with few femtosecond duration

ELI-ERIC call instruments
Nonlinear THz Spectroscopy Facility

user ready
8 user campaigns

- THz pump—THz probe measurements
- Charge carrier dynamics
- Lattice anharmonicity
- THz nonlinearities
- Charge separation dynamics in biological molecules/complexes
- [spectrally resolved THz imaging]

Pump laser (cryo-cooled Amplight)

- Wavelength: 1.03 µm
- Pulse duration: 200 fs
- Pulse energy: ≥6 mJ
- **Repetition rate: 1 kHz**
- Jitter to an external clock signal: ≤100 fs

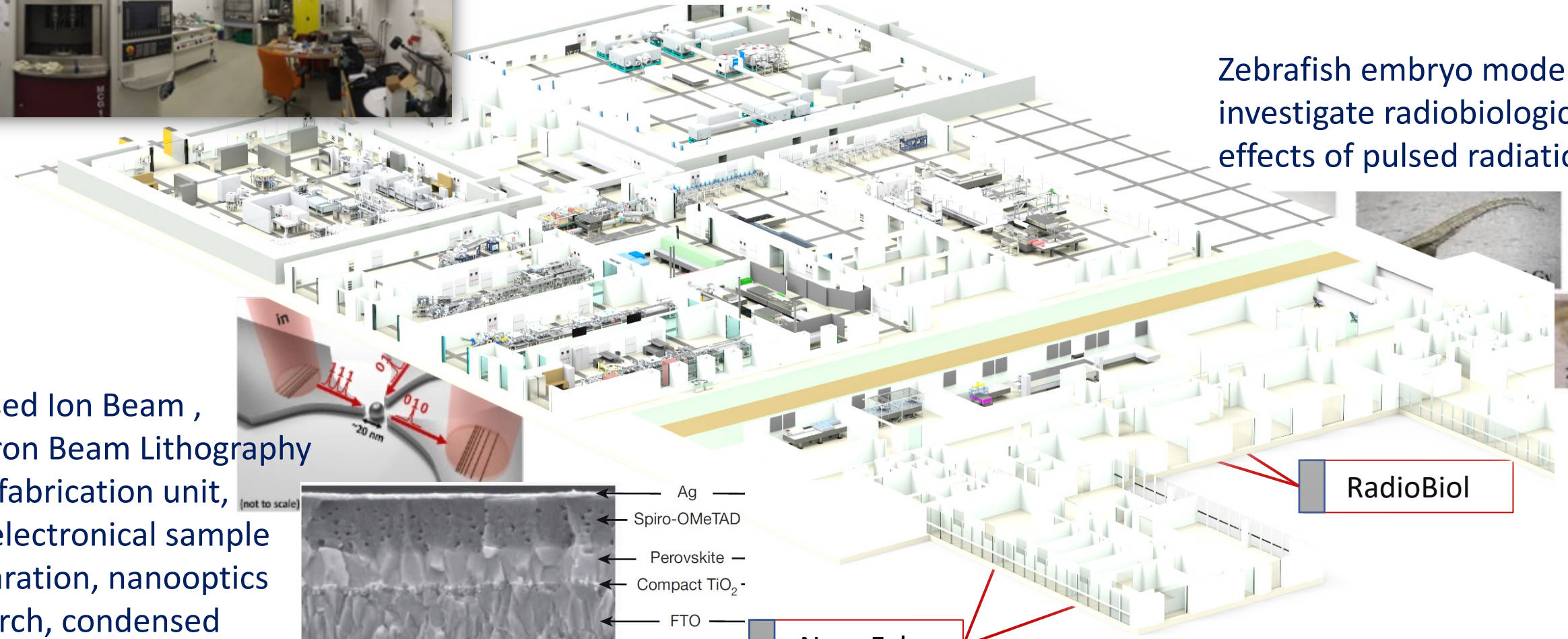
PÉCSI TUDOMÁNYEGYETEM
UNIVERSITY OF PÉCS

THz source:

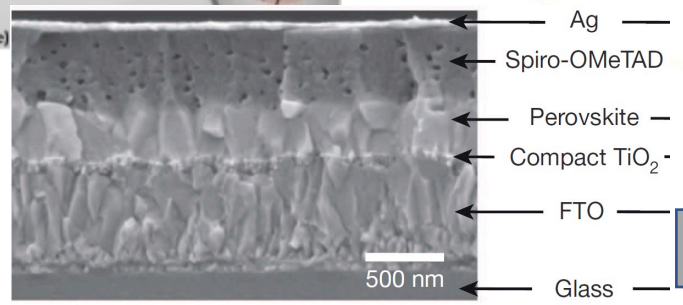
- **pulse energy: ≥10 µJ**
- spectral maximum: in the 0.3-0.6 THz range
- useful spectral content: 0.15-1.5 THz
- **peak THz field at the sample: ≥200 kV/cm**

Auxilliary facilities

Mechanical and electrical workshops
(incl rapid prototyping)
Optical workshop for custom optics and coatings
(incl advanced metrology)

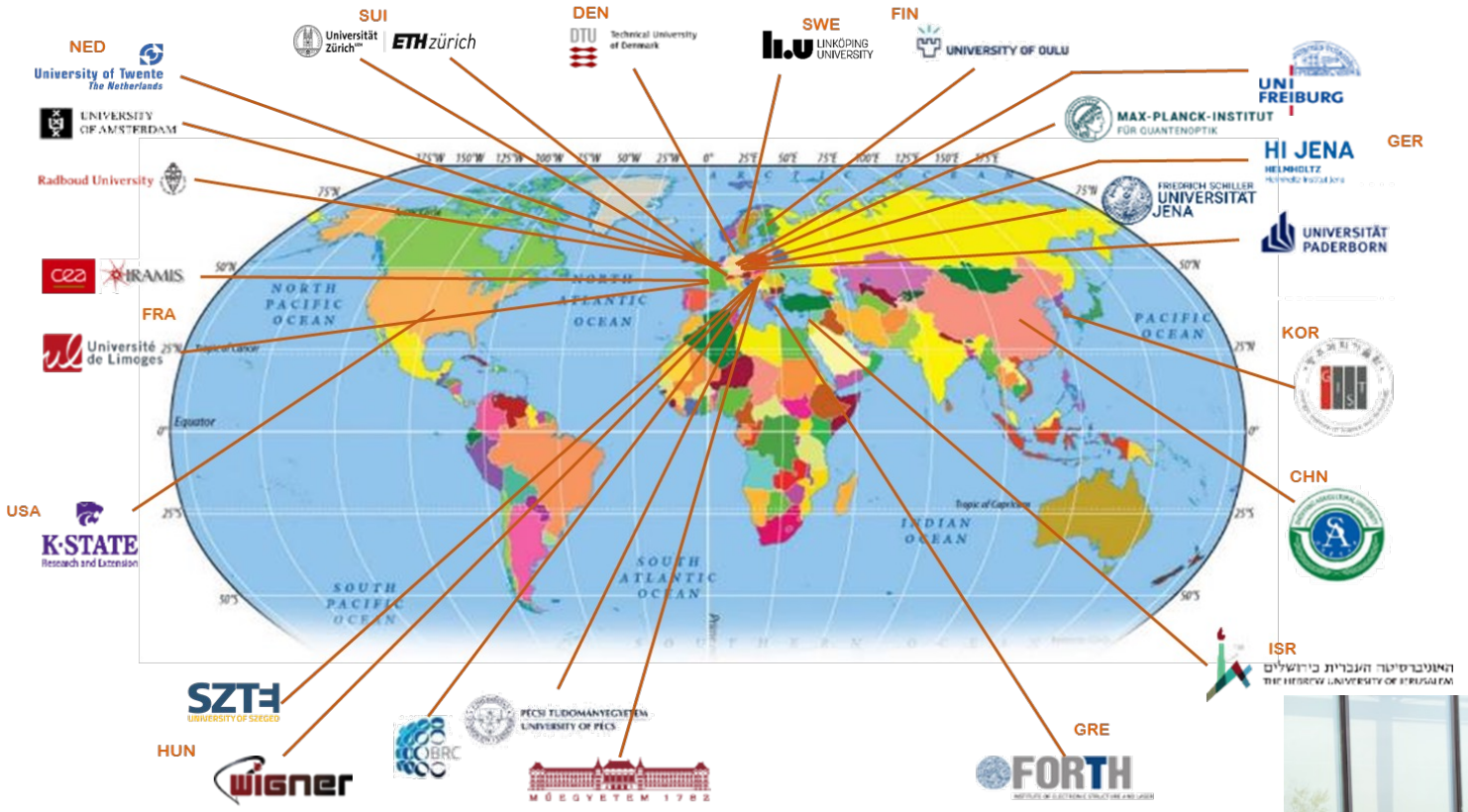


Zebrafish embryo model to investigate radiobiological effects of pulsed radiation.



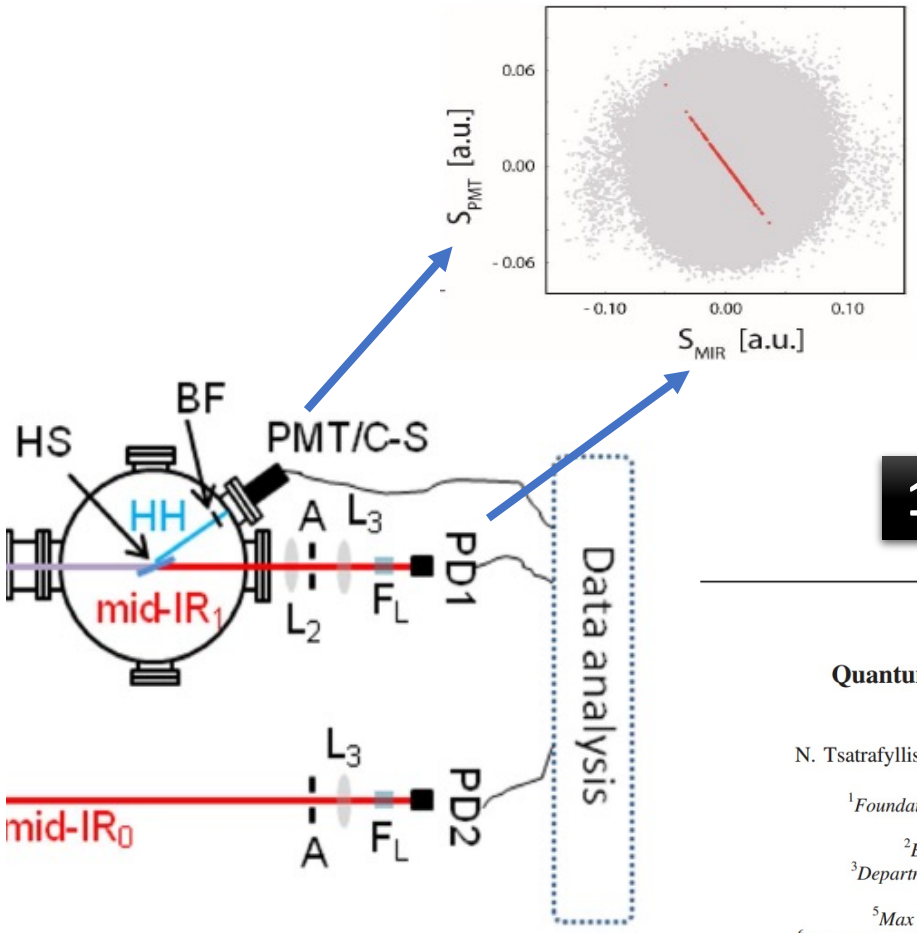
Focused Ion Beam , Electron Beam Lithography Nanofabrication unit, optoelectronical sample preparation, nanooptics research, condensed matter analysis

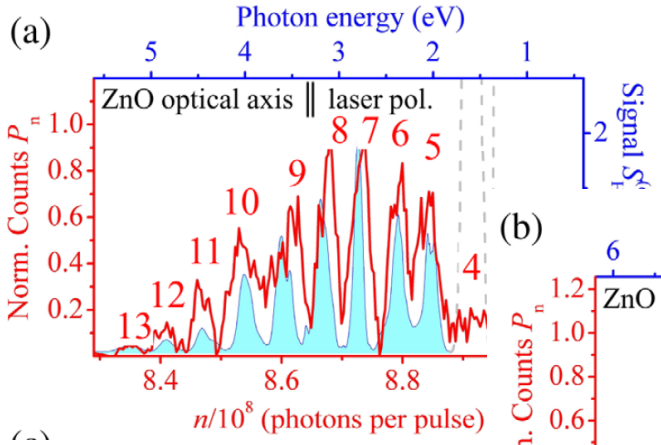
User experience gathered

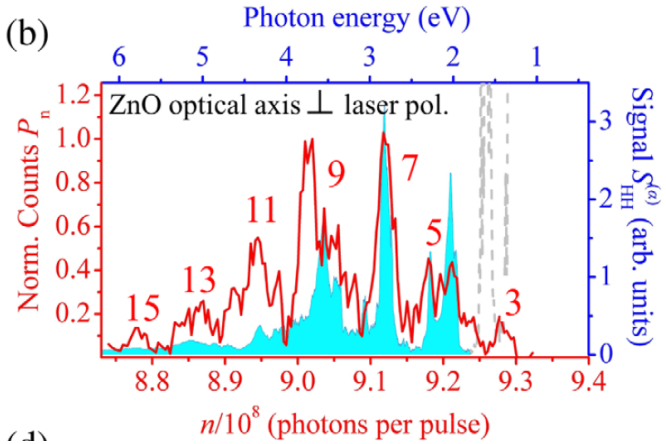


Equipments	User ready	User expts
MIR	2017	14
HR1	2017 (40 fs)	7
SEA	2019	2
SYLOS 2	2019	1
GHHG SYLOS Comp	2021	1
THz pump	2021	1
THz Spectr	2020	8
ChemReac (TAS, GPRC)	2020	2
NanoEsca	2020	2

ELI-ALPS early user experiments
The quantum spectrometer







1st User paper from ELI-ALPS

PHYSICAL REVIEW LETTERS **122,** 193602 (2019)

Quantum Optical Signatures in a Strong Laser Pulse after Interaction with Semiconductors

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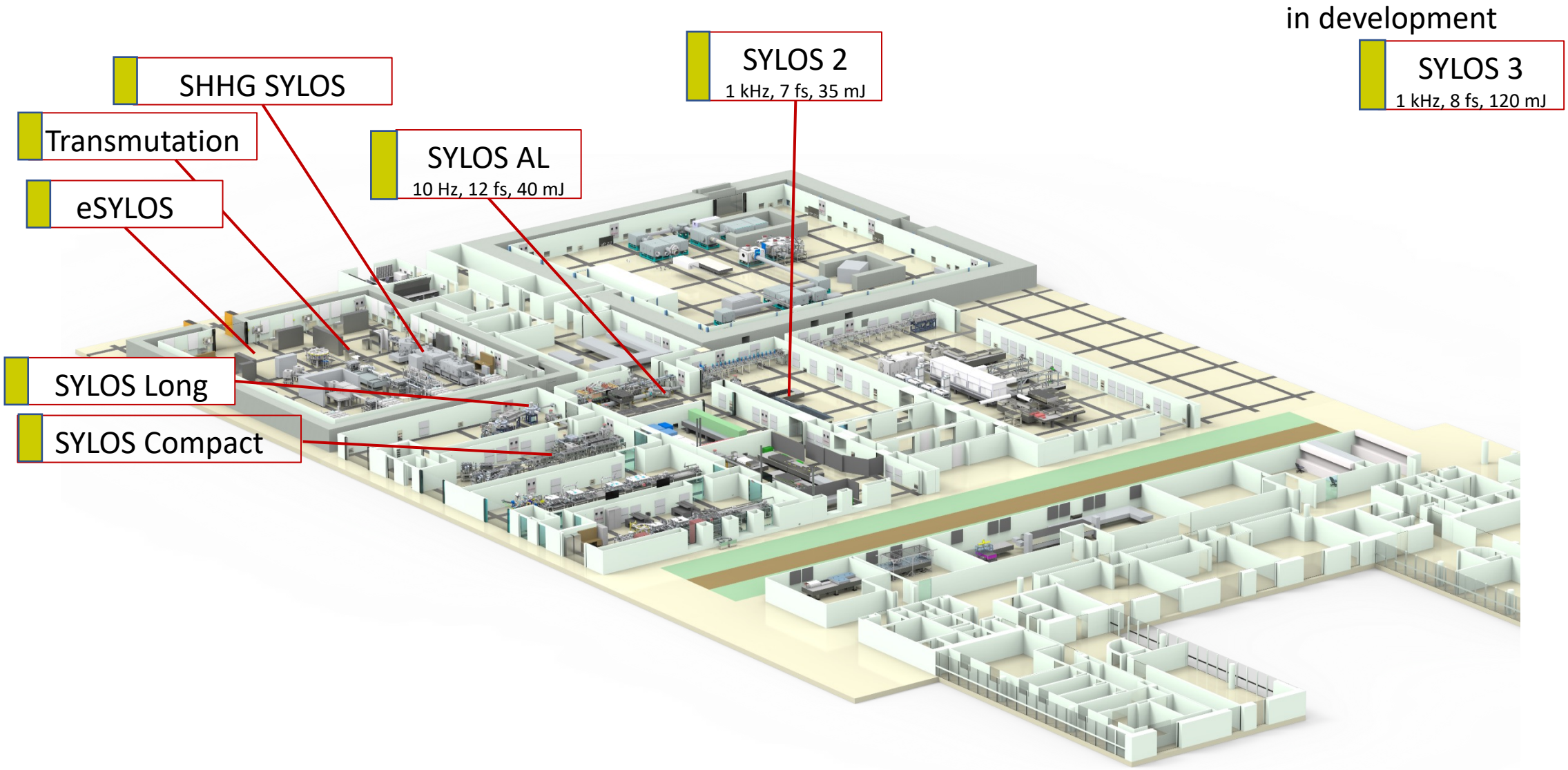
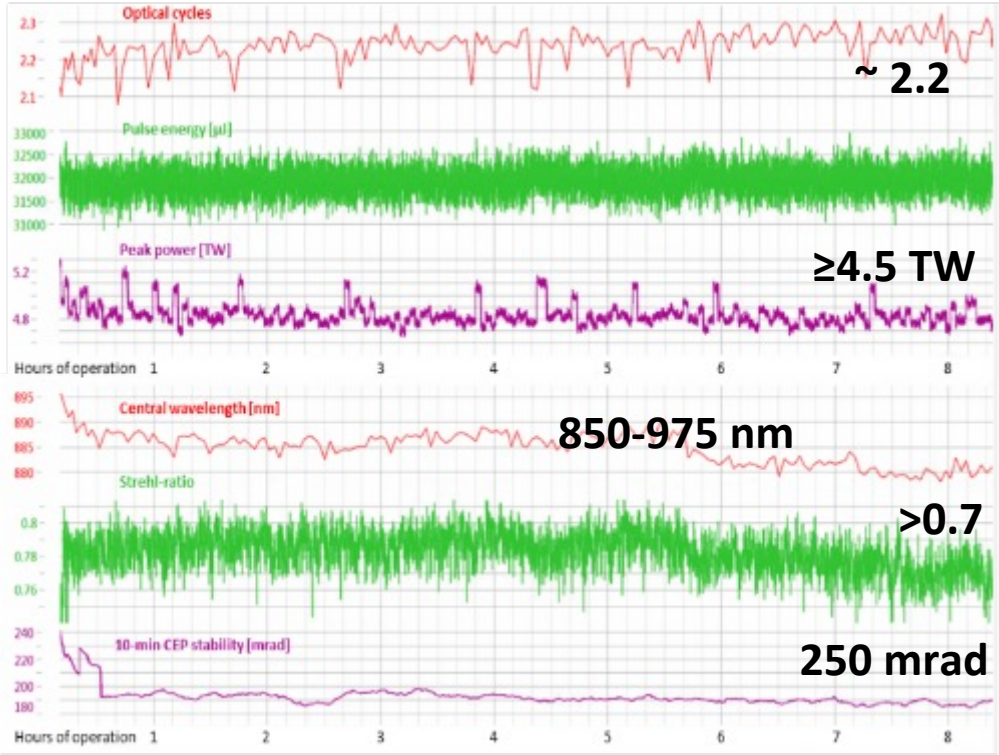
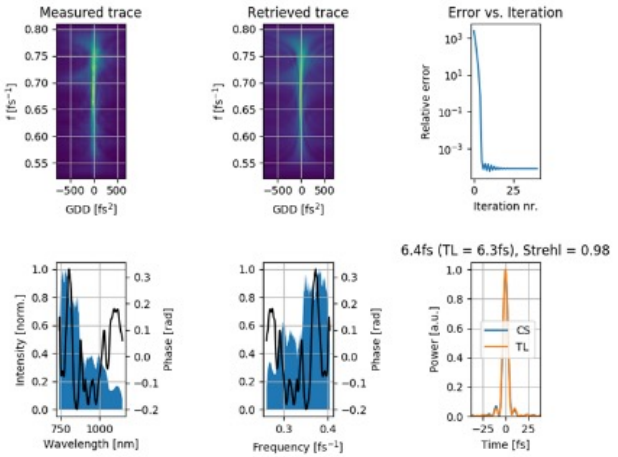
Other upcoming instruments
SYLOS activity 1 kHz



Status of SYLOS2 laser



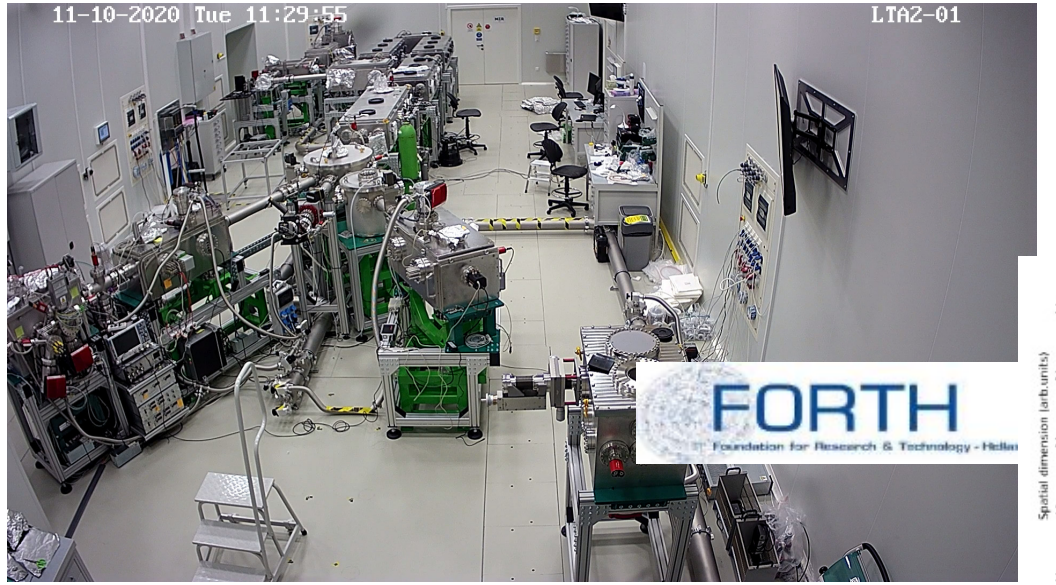


user ready

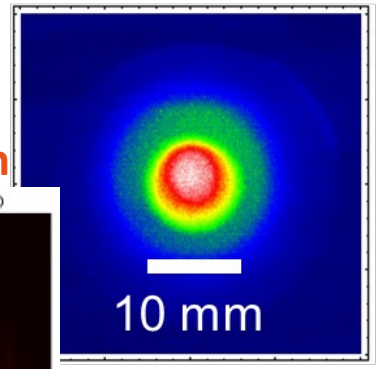
3 user campaigns

	Parameters	Status	User readiness
SYLOS 2	*1 kHz, <6.5 fs, 30 mJ, CEP*	*Operational*	*since May 2019*
SYLOS alignment	*10 Hz, <12 fs, >40 mJ*	*Operational*	*since Jan 2019*

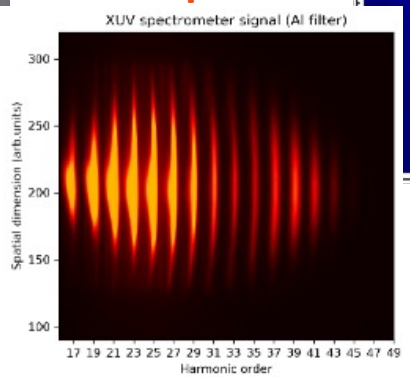
SYLOS GHHG Compact in commissioning



XUV beam profile



XUV spectrum



User ready by Q2 2022

Harmonics 15+17

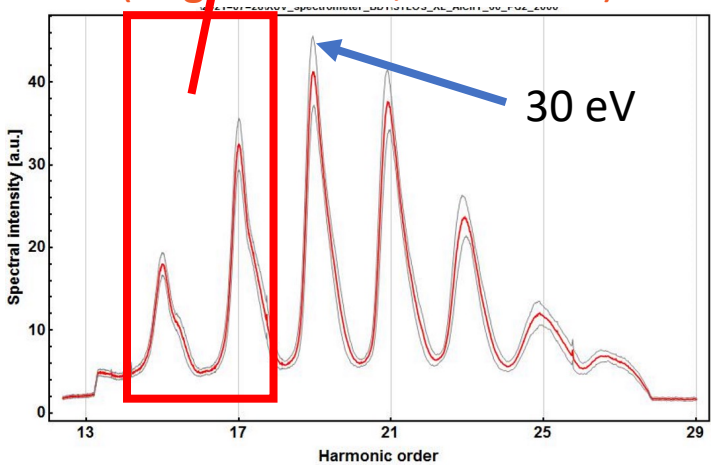
- **308 nJ** at generation
- 7 nJ into end-station

Entire spectrum

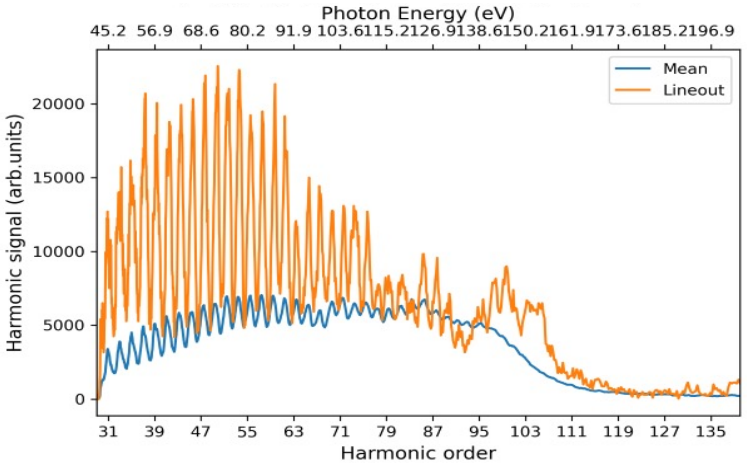
- estimated **1 µJ** at generation

1 user campaign

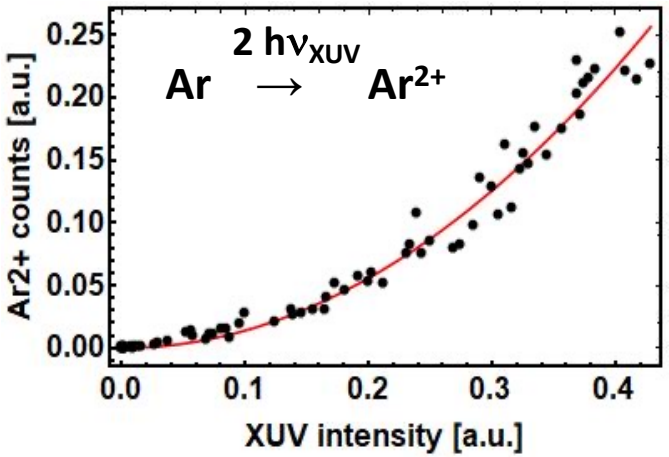
XUV spectrum of **Xenon**: Pulse energy of 360 nJ (at generation, HO 13-15)



XUV spectrum of **Neon**: cutoff at 150 eV



Nonlinear XUV process



SYLOS GHHG Long in commissioning

User ready by Q3 2022

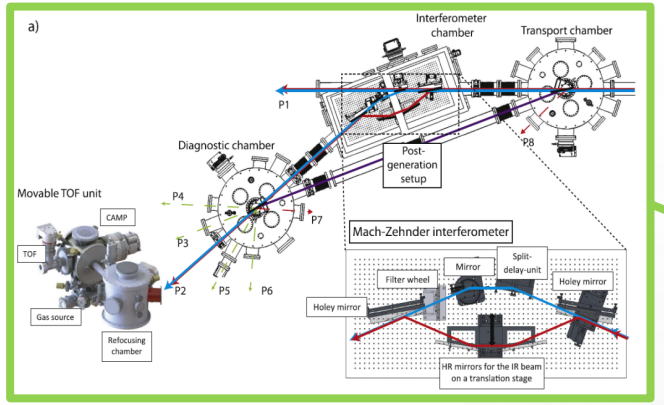
User ready by Q3 2022

Refocusing
Interaction

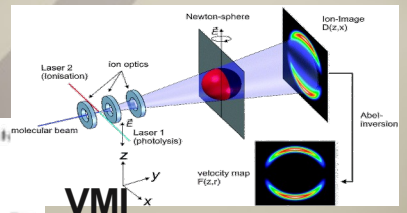
IR focusing

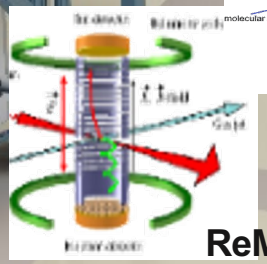
GHHG

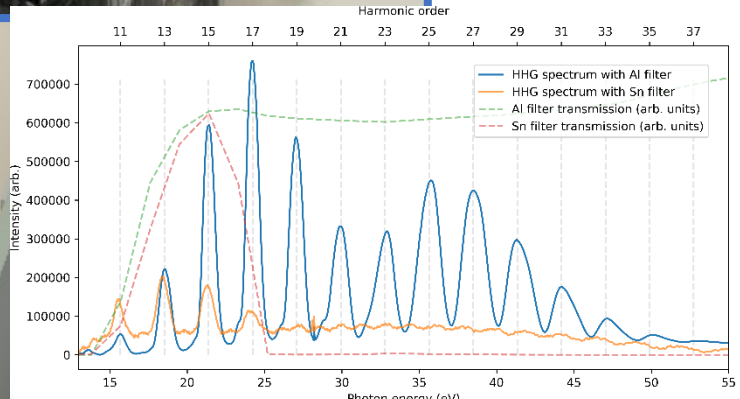
Turning



Interferometer
Split-and-Delay



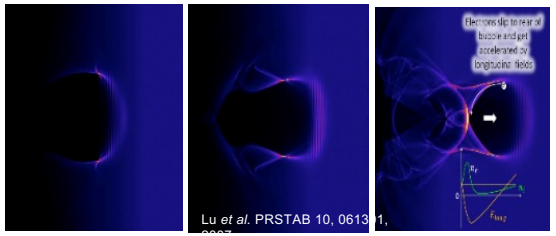


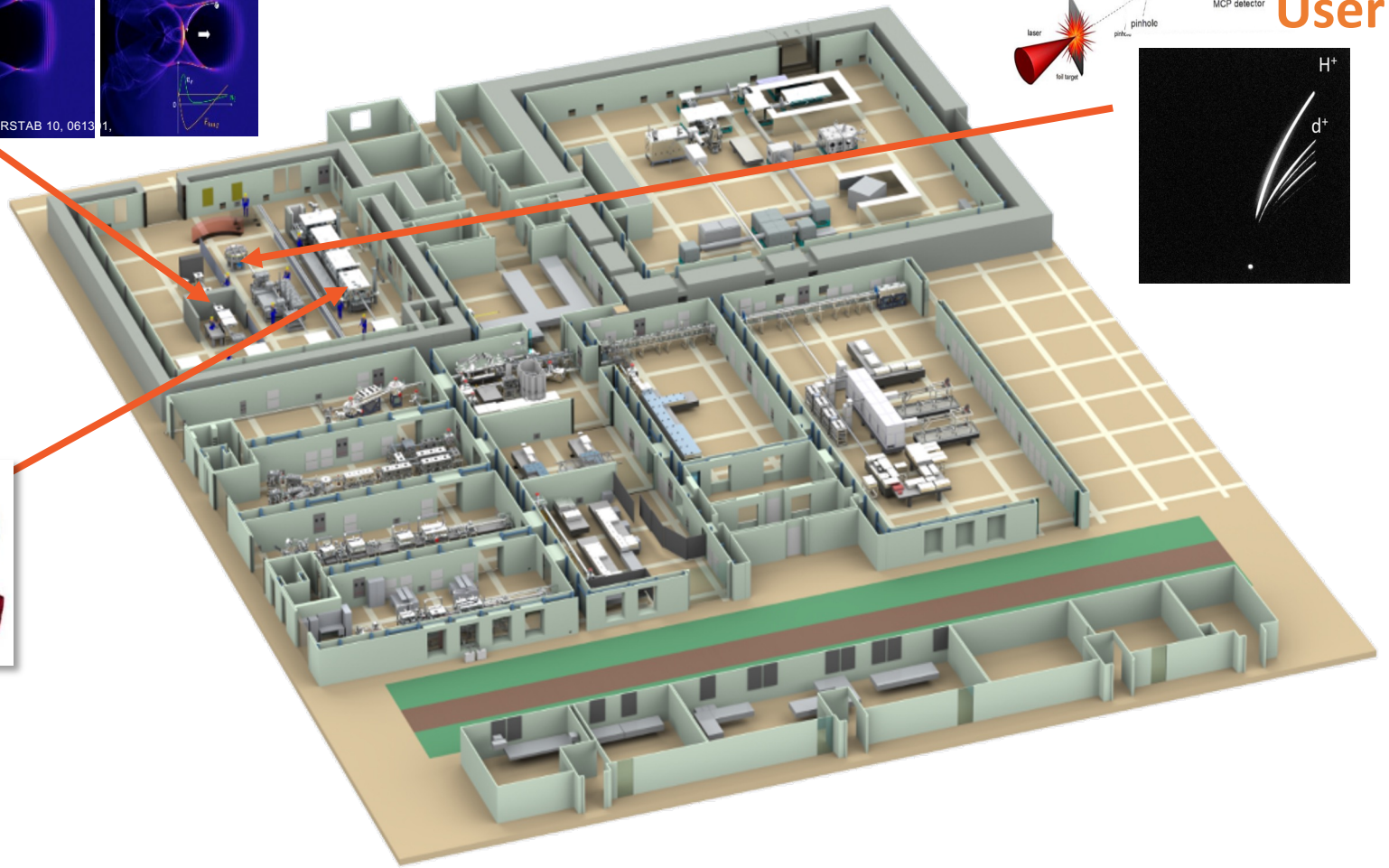


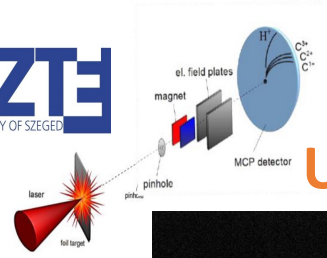
Pump-probe options

XUV + XUV
XUV + IR
XUV + XUV + IR
XUV + XUV + IR + IR / SHG / THG / VUV / XUV

Other upcoming instruments
SYLOS driven high field interactions

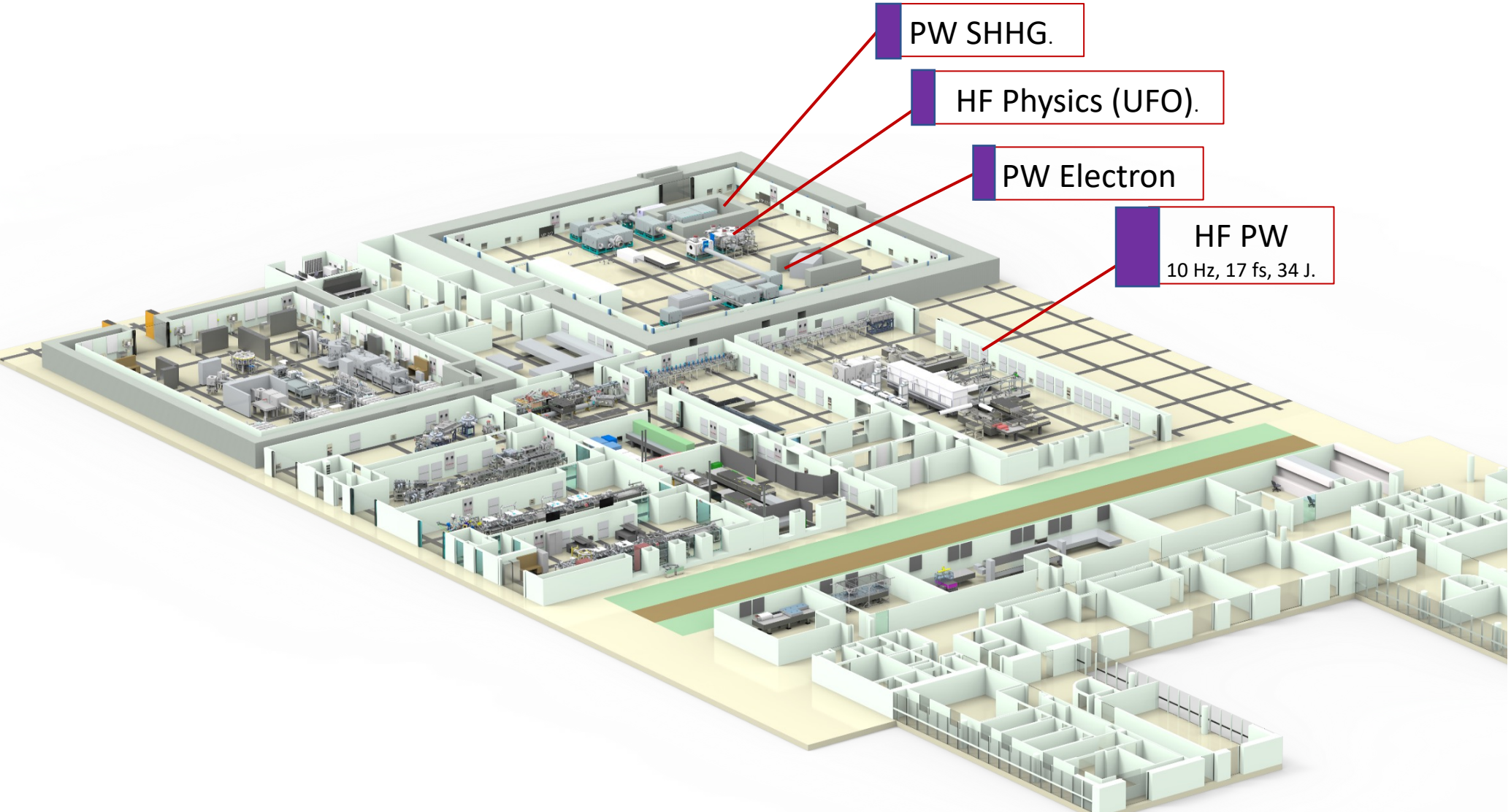




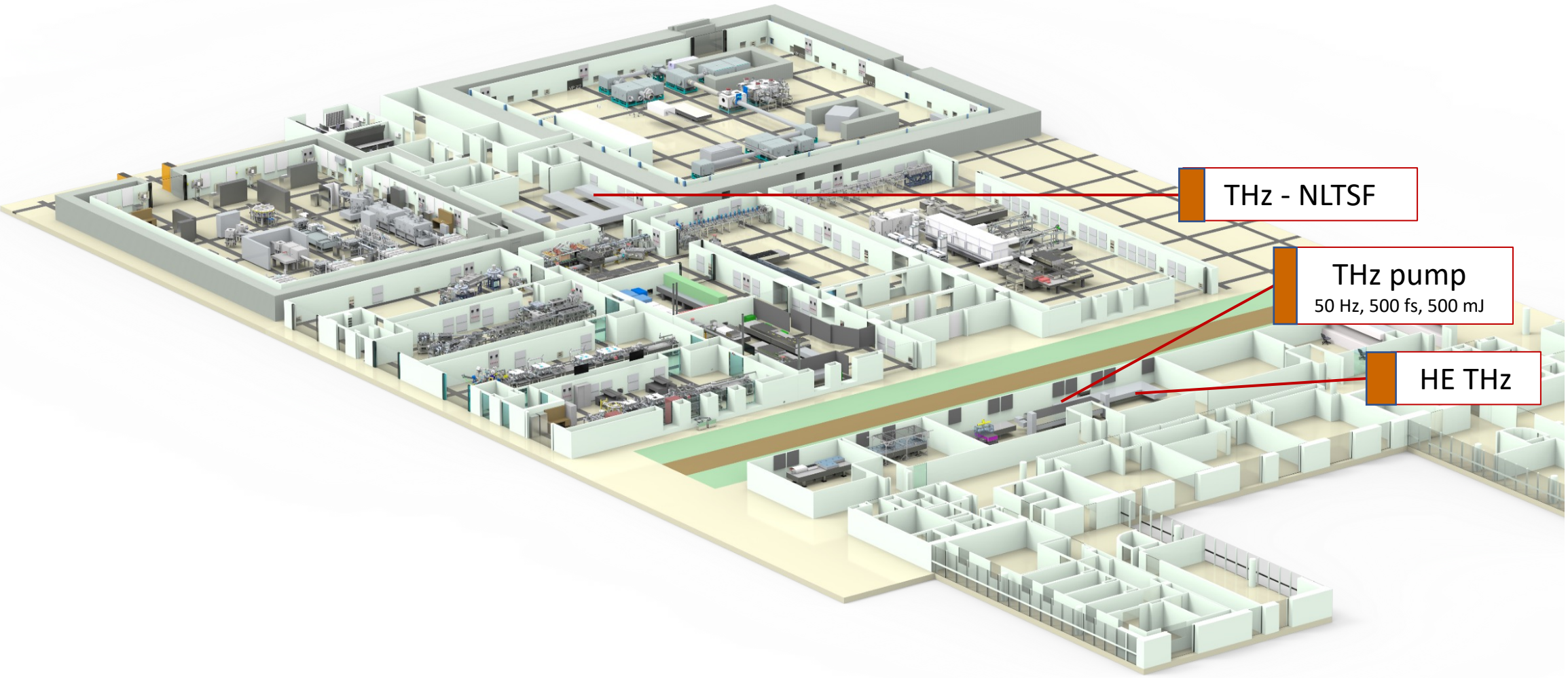


User activity

Other upcoming instruments
The HF PW activity 10 Hz



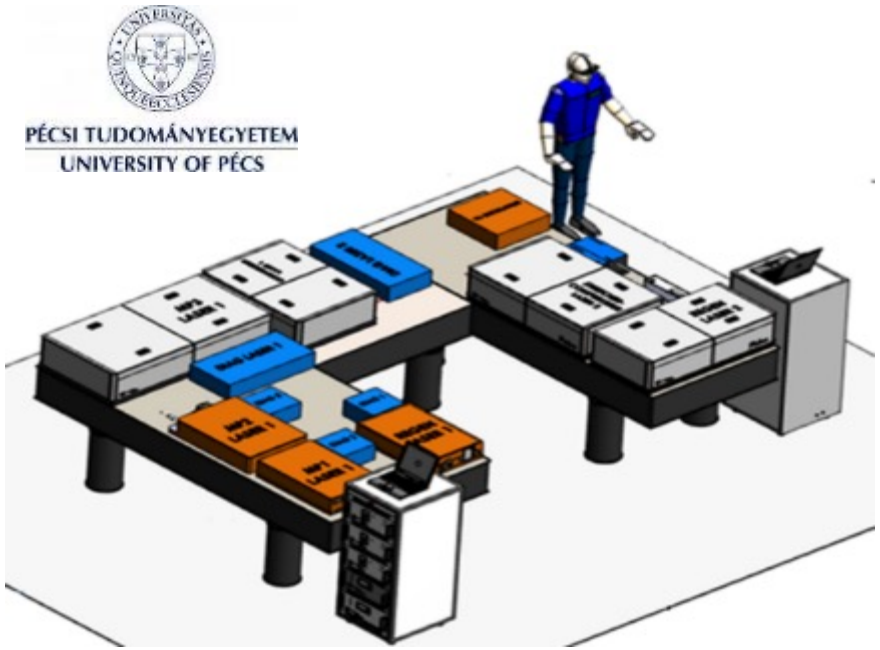
Other upcoming instruments
THz activity 0.15-1.5 THz



Other upcoming instruments
High Energy THz Beamline

user ready

- Materials in extreme THz fields, phase transitions
- Molecule orientation & alignment
- Electron acceleration, manipulation, and bunch characterization
- Relativistic (~1 MeV) ultrashort electron source for time-resolved diffraction & imaging (microscopy)
- Proton post-acceleration



Pump laser: Amplitude Technologies

- Wavelength: 1.03 µm
- Pulse duration: 500 fs
- Pulse energy: ≥500 mJ
- **Repetition rate: 50 Hz**
- Synchronized short-pulse output:

  0.8 µm | 100 fs | 1 mJ | 1 kHz

THz source:

- **pulse energy: ≥1 mJ**
- spectral maximum: in the 0.3-0.6 THz range
- useful spectral content: 0.15-1.5 THz
- **waveform: <2 cycles**



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