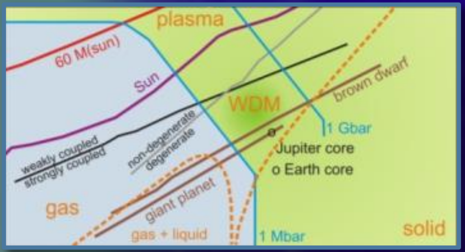
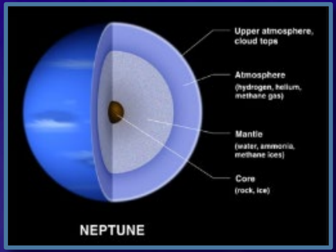
HED instrument at European XFEL and HIBEF user consortium

Ulf Zastrau
Leading scientist
Group leader, HED science instrument

3rd town hall meeting, Nov 3rd, 2021





Unique capabilities arise when:

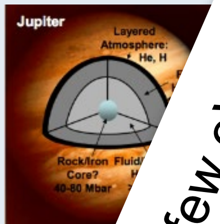
Couple XFEL beam to powerful drivers

- Diamond Anvil Cells HiBEF
  dynamic DAC; pulsed laser heated DAC; double-stage DAC
- Powerful optical lasers
  100 J 15 ns 10 Hz (DiPOLE); 300 TW 25 fs 10 Hz (ReLaX) HiBEF
  0.2 – 2 J 15 fs 800 nm 1 MHz; 1– 40 mJ 800 fs 1 MHz (pp-laser)
- XFEL split&delay line (2022) Bundesministerium für Bildung und Forschung
  x-ray pump-probe, 0-20 ps delay
- 60 T pulsed magnetic field coil (2022) HiBEF
  cryogenic sample environment

HED – research at extremes

Laser Compression

Shock & ramp compr



XRD, IX

Long-p laser

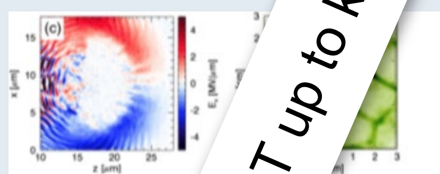
Relativistic Laser-Plasmas

Electron transpor

Instabilities and filam ,

Particle acceler

High EM fi



Multi-10 laser

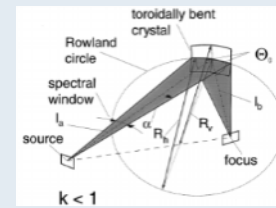
Advanced methods

Spectrometers

Advanced focusing

SAXS energy analyzer

Phase contrast imaging



high density $\rho > \rho_0$, T < few eV

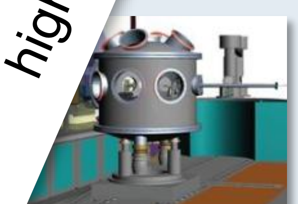
solid density $\rho = \rho_0$, T up to keV

Diam vil Cells

Fast piezo DAC

Puls heated DAC

-stage DAC

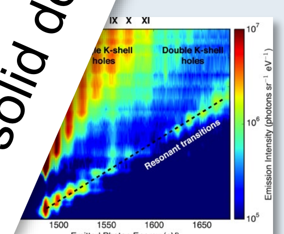


18 to 25 keV

Isochor excitation

Tra roperties,

H oms, rates



XES, IXS, XRD

Tight focusing

Further projects

Isobaric heating

Cryogenic jet targets

High-rep solids targets

EMP-hard X-ray detectors

High-purity polarimetry

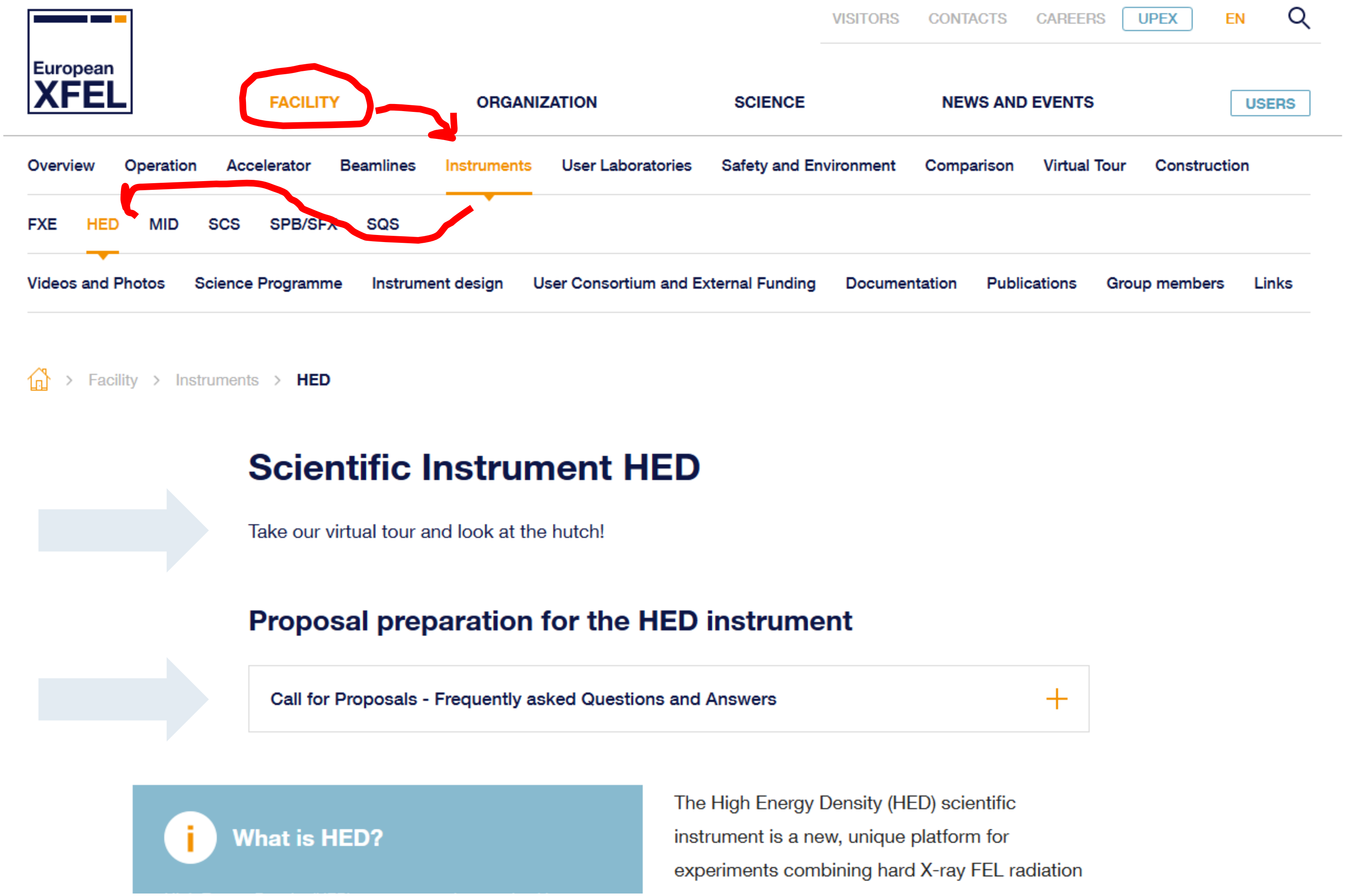
Laser-shocked DAC

GISAXS

Instrument papers

- **General overview of the HED instrument**
  - Zastrau, Appel, Baehtz et al., J. Synchrotron Rad. (2021). 28, 1393–1416The experimental platform for XRD from Diamond Anvil Cells
  - Liermann et al., J. Synchrotron Rad. (2021). 28, 688-706
- Design and performance of the HAPG von-Hamos spectrometers
  - Preston et al., Journal of Instrumentation, Volume 15 (2020)
- Design and performance of the meV high resolution setup
  - Wollenweber et al., Review of Scientific Instruments 92, 013101 (2021)
- Design and performance of the SAXS HAPG mirror
  - Smid et al., Review of Scientific Instruments 91, 123501 (2020)
- ReLaX: the HiBEF high-intensity short-pulse laser driver
  - A. Laso Garcia et al., High Power Laser Science and Engineering, 1–15 (2021) - https://doi.org/10.1017/hpl.2021.47

https://www.xfel.eu/facility/instruments/hed/



The conditions expected for this allocation period are listed below. V**erification about specific feasibility conditions with the instrument teams is required.**

Bunch duration [rms fs]	**10-25 fs**
Max. intra-train frequency [MHz]	4.5 MHz (standard 2.25 MHz)
Typ. number of pulses*	1-400

	Photon Energy range	Expected Pulse Energy range**
SA2	5.8-9.3 keV	2 mJ +/- 20%
	>9.3-12 keV	1 mJ +/- 20%
	>12 – 18 keV	0.5 mJ +/- 20%
	>18keV-24keV	TBD

* Bunch distribution: 400 X-ray pulses per instrument assume equal distribution at 2.25 MHz operation. Higher or smaller numbers for higher/smaller intra-train frequency. Max. 2250 electron bunches within 500 µs are available for distribution to the instruments (4.5 MHz)
** Pulse energy depends on bunch charge, electron energy and photon energy.

1. The above parameters correspond to the *standard* **SASE** operation mode.
2. The following *Special* modes are available for HED, but require more tuning and are less reliable:
   a. Hard X-ray **Self-Seeding** (7 - 14 keV) -> for experiments which benefit from smaller bandwidth of ~ 1 eV
   b. Hard X-ray **2-color w. variable delay** (6 – 10 keV; 0 – 0.5 ps) and
   c. Short bunches (< 10 fs). Scheduling requires a sufficient number of experiments at several instruments. Time-diagnostics is only partially available → for ultrafast studies
   d. Full trains with << 10 Hz rep rates (~ 2250 pulses) → especially interesting for dDAC experiments

   Experiments requesting these *special* modes should address the development of new techniques and fields and are expected to involve large communities and facility staff. If included in final schedule, continuous (24 hrs) beam delivery would be planned in this case. Since there is a vast range of detailed specifications for these special modes, proposers are requested to contact the respective instrument staff in order to clarify requirements.

Details on Special mode 1d: Full trains with << 10 Hz rep rates (~ 2250 pulses)

- EuXFELs timing system is absolutely capable of this mode. However the various feed-backs and feed-forwards that are presently optimised for each beamline separately will have to work on a common setpoint.
- We would tune for a 'compromise' working point that works for all cases, but would not reconfigure the linac for a single pulse every minute or so. So every SASE would operate with a not optimal working point all the time.
- As a consequence we estimate a systematic **about 30% less intensity at compared to the standard modes.**
- The accelerator would run normally, where each train would deliver a portion of the RF window to each SASE. Then, every minute or so, a full train (full RF window) would go ONLY to SASE2 (HED). This means that SA1 and SA3 would “miss” one train every minute.

HE-OL: DIPOLE laser community proposal for a single, centrally coordinated community proposal

For the run 7 in 2019 the DIPOLE laser was offered for a single community user assisted commissioning proposal with a limited parameter set in terms of laser properties. This proposal was selected to be scheduled in 2022.

Due to ongoing technical challenges and Covid19-related delays, this DiPOLE beamtime can only be scheduled in the second half of 2022. Other competing proposals are not yet feasible before the capability of the laser and the shock platform ave been demonstrated. Therefore, **the submission of new DiPOLE proposals is unfortunately not possible in run 8.**

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We anticipate that proposals using the shock platform and the DiPOLE laser can be submitted within the next call for proposals, in May 2022 (beamtime in 2023).

Standard configurations for run 8 (allows to schedule more experiments back-to-back)

Diamond Anvil Cell (DAC) standard configuration

- IC2 standard DAC setup, symmetric DAC cell support for users who need cells. user supplied BX90 with adapters.
- optical observation microscope, streaked pyrometry for x-ray heating.
- 18 keV SASE, max rep rate 4.5 MHz, > 0.5 mJ pulse energy from the
- undulators (not accounting for beamline transmission)
- 5-15 micrometer focal spot size (fixed at 5 μm, but effectively larger depending on beam pointing stability)
- Detectors: AGIPD mini -half detector and VAREX flatpanel
- Requirement to contact HED instrument team for feasibility check.

ReLaX-SAXS-PCI standard configuration.

- IC1 chamber, 100 TW ReLaX laser incident on target at 45° w. r. t. XFEL (no normal incidence of laser on target)
- SAXS+PCI @ 8.15 keV SASE (tunable within reasonable range), ca. 1 mJ per pulse, 2.25 MHz maximum rep rate.
- + 5-50 μm spot size (both X-ray and ReLaX), no nanofocus possibility.
- + PCI resolution of about 1μm
- Backward HAPG x-ray spectrometer. Forward spectrometer can only be added of SAXS diagnostics is not used.
- Laser diagnostics (upon request): EMP, electron, bremsstrahlung and proton diagnostics (contact HED staff for details before submission).