# Status and Targetry of European XFEL and HED scientific instrument at the European XFEL

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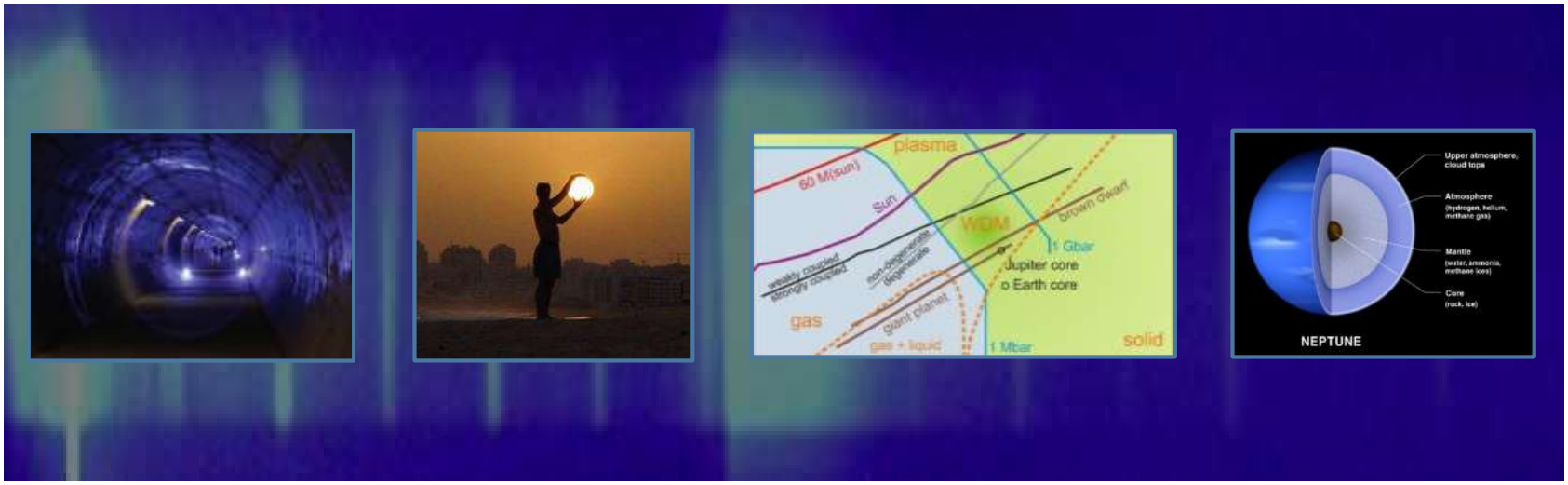
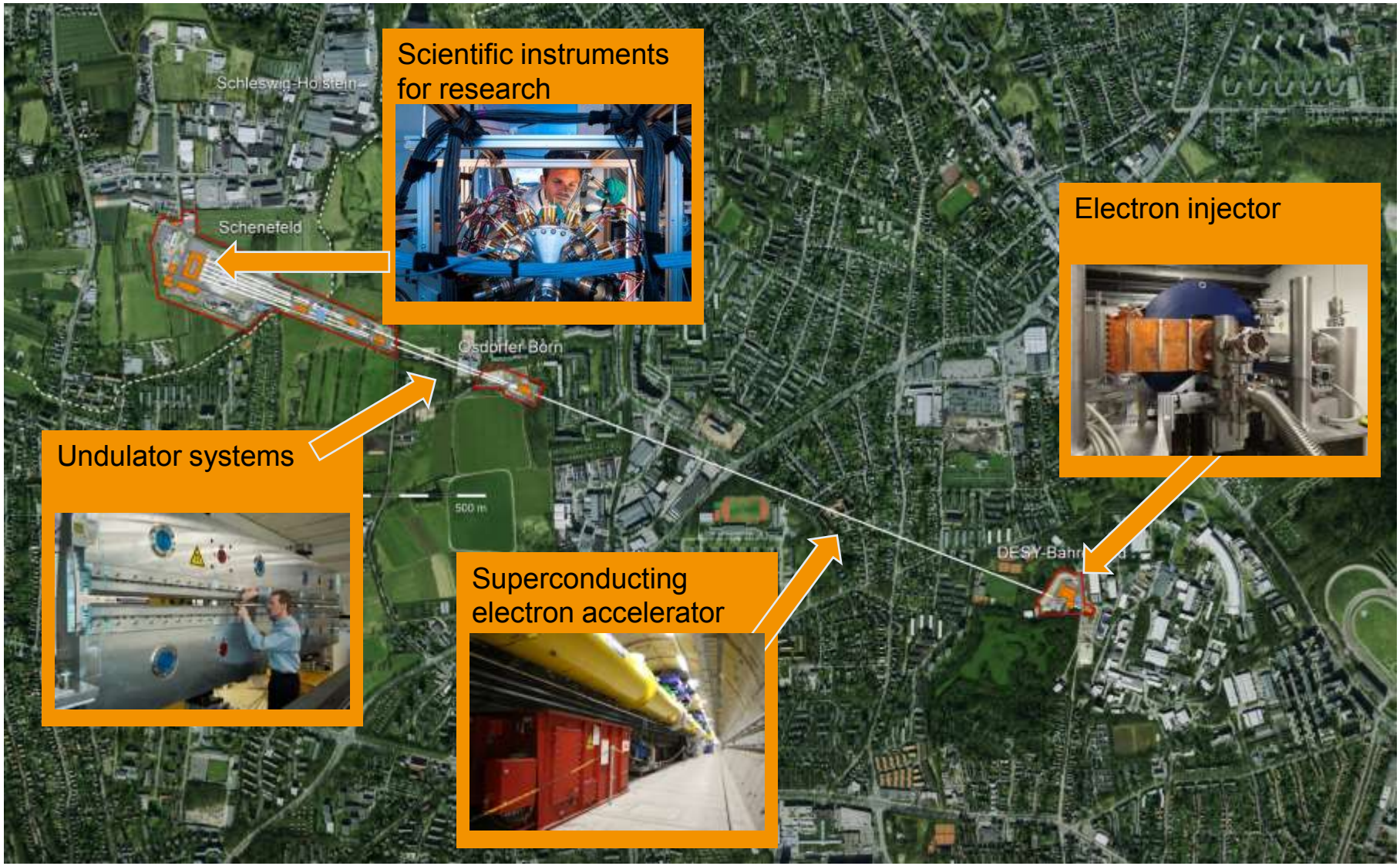
Group leader for HED science
European XFEL

2nd EUCALL target network workshop, ELI, May 29-30, 2018

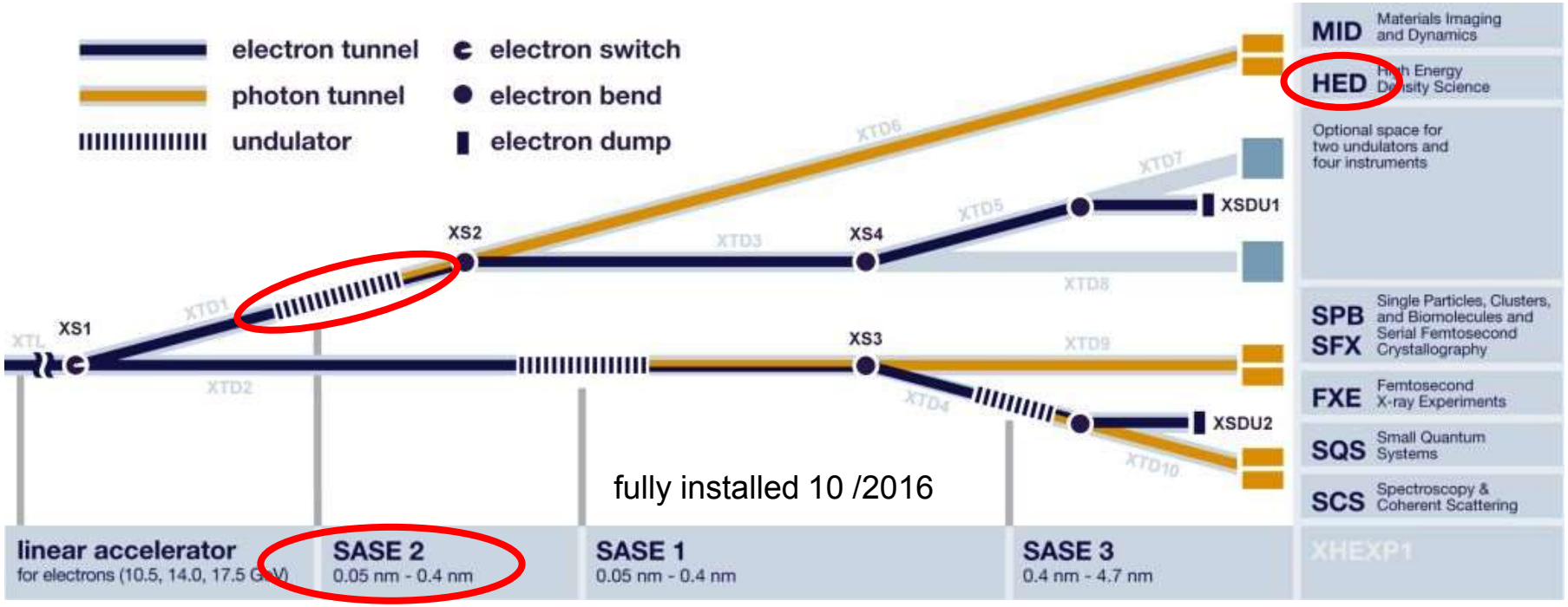


# European XFEL—a leading new research facility

# How it works: a closer look at the facility



# European XFEL: beamlines and instruments




- Cool down of accelerator modules to 2 K — Dec. 2016
- 9 keV lasing SASE1, 1 mJ / 30 bunches — June 2017
- Commissioning SASE1 FXE/SPB — July 2017
- First experiments at SASE1 — Sept. 2017
- First lasing in SASE 3 (900 eV 2 mJ) — Feb. 2018

# Simultaneous lasing at SASE-1,2,3 - May 2nd

# Third Call for proposals is currently open

- **First time including all 6 scientific instruments**
- Beamtime will be allocated to successful proposals in November and December 2018 and from the beginning of February to the end of June 2019.
- The following scientific instruments will be made available during this period:

| | |
|---|---|
| Femtosecond X-Ray Experiments (**FXE**) | at Beamline SASE1 |
| Single Particles, Clusters, and Biomolecules and Serial Femtosecond Crystallography (**SPB/SFX**) | at Beamline SASE1 |
| High Energy Density Matter (**HED**) | at Beamline SASE2 |
| Materials Imaging and Dynamics (**MID**) | at Beamline SASE2 |
| Spectroscopy and Coherent Scattering (**SCS**) | at Beamline SASE3 |
| Small Quantum Systems (**SQS**) | at Beamline SASE3 |

# Unique capabilities arise when:

## Couple XFEL beam to powerful drivers

**Powerful Optical Lasers**

- 100 J 15 ns 10 Hz → second-of-its kind after HILASE
- 400 TW 30 fs 10 Hz
- Proposal for kJ laser > 2022

**Diamond Anvil Cells**

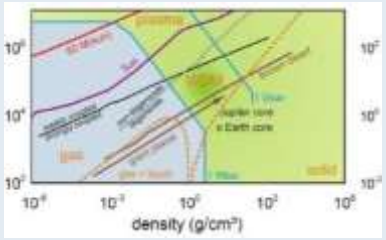
- dynamic DAC
- pulsed laser heated DAC
- double-stage DAC

**X-ray pump (-probe)** (tight focus; BMBF Split-and-Delay Line )

**Pulsed magnetic fields** (< 60 T, proposal)

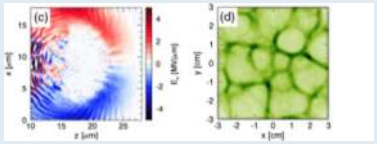
# HED instrument: scientific agenda

**Laser Compression**
Shock & ramp compression



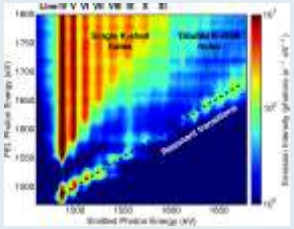

IC 2 for precision XRD
IC 1 for XRD, IXS, XES
DIPOLE-100X ns laser

**Relativistic Laser-Plasmas**
Electron transport,
Instabilities and filamentation,
Particle acceleration,
High EM fields



IC 1
Multi-100 TW laser

**Isochoric X-ray excitation**
Transport properties,
Hollow atoms, rates

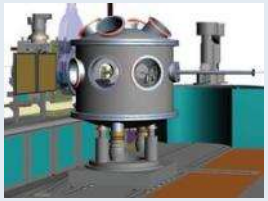


IC 1 for XES, IXS, XRD
Intense X-ray pulses, SDL

**Condensed Matter in Strong Magnetic Fields**
Correlated systems,
magnetic order,
superconductivity

Goniometer in IA 2
split or 60 T solenoid coils

**Diamond Anvil Cells**
Fast dynamic piezo DAC
Pulsed laser heated DAC
Double-stage DAC



IC 2 for precision XRD
Dynamic DAC, pulsed lasers

Many more:

Strongly excited materials
QED vacuum birefringence
Self-sustained reactions
…

# Types of targets needed (selection)

- Relativistic laser plasmas
  - Plain foils (polycrystalline)
  - Foils with micro-dots, embedded structures (gratings, interfaces), cones, …
  - Jet targets (high rep rate proton / ion acceleration)
- Laser shock compression
  - Layered targets (CH ablators; sandwich/tapers from CH, diamond, … )
  - LiF/sapphire/quartz windows for VISAR, defined glue layer
- X-ray heating
  - Foils (maybe sandwiched between CH taper)
  - Locally doped samples
- Diamond Anvil Cells
  - Grow crystals of certain minerals/metals, also under pressure
  - FIB preparation, micro manipulation

# High repetition rate – demands for mass production

**Typical experiment is 5 days 12 hours each**

- Reduce by 1 day for alignment
- Per campaign day, effective shot time is 25% (3h)
- Operation at 1 Hz is more realistic than 10 Hz (positioning)

→ 4 * 3 hours ~43’000 seconds → **40’000 targets**

**For solid targets, we need:**

- Mass production
- Mass metrology
- Debris management (!)

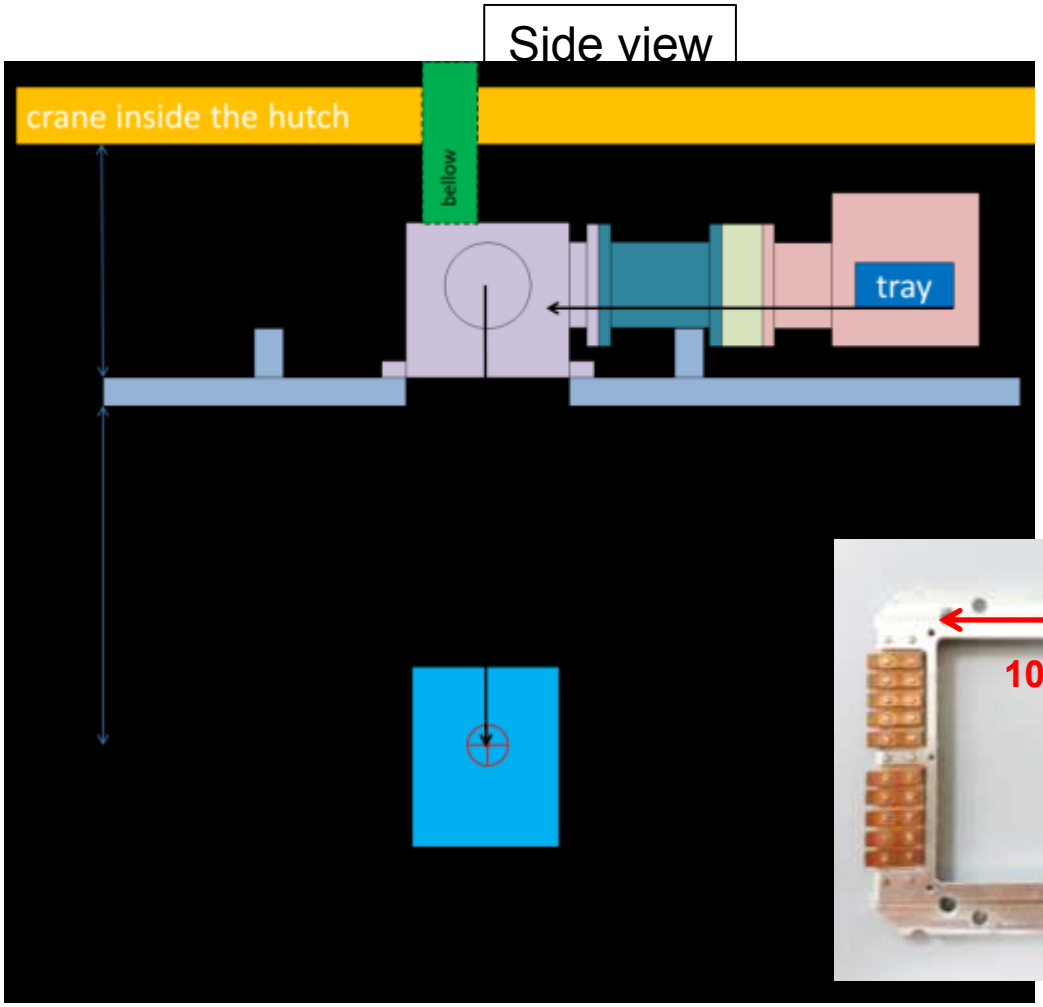
# How many samples fit onto a sample frame?

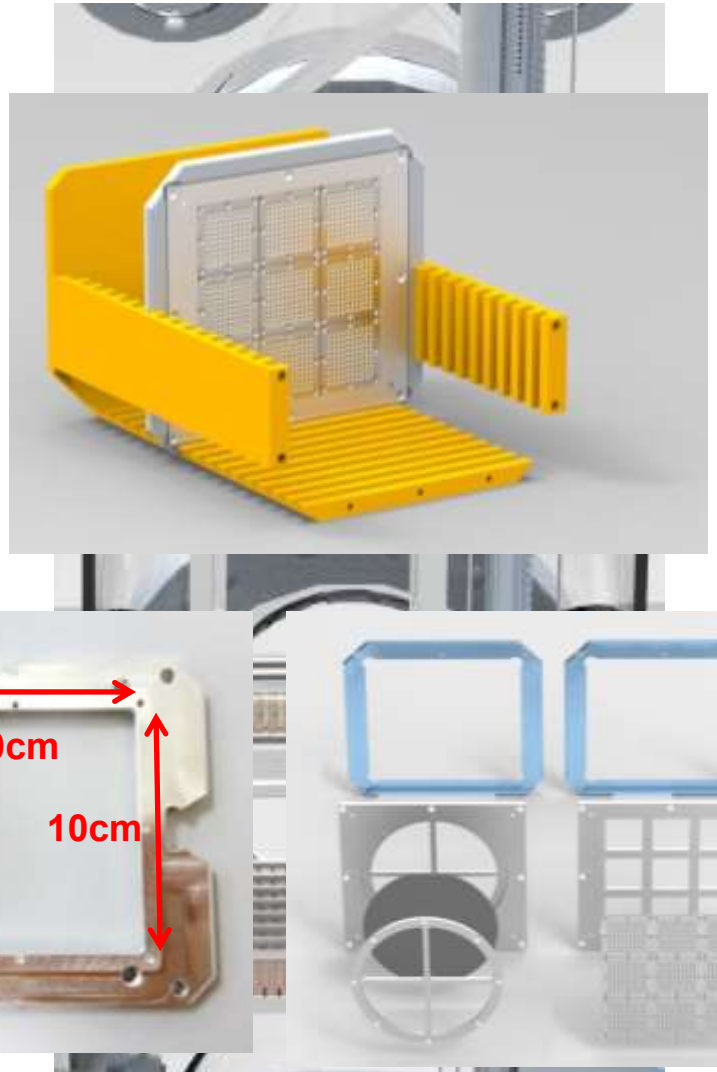
**Sample frame 100 x 100 mm²**

- X-ray heating
  - Shots can be placed every 0.2 mm → 500x500 shots = 250'000
    at **10 Hz** this target frame could last **7 hours**.
- Relativistic laser plasmas
  - Shot can be placed every 5 mm: 20 x 20 shots = 400 shots
    at **1 Hz** this target frame could last **7 minutes**.
- Laser shock compression
  - Shot can be placed every 5 mm: 20 x 20 shots = 400 shots (good phase plates!)
    at **0.1 Hz** this target frame could last **1 hour.**

- **Time to change target frame ~ several minutes.**
  **…using an in-vacuum sample change mechanism.**

# IC1 – Sample exchange system

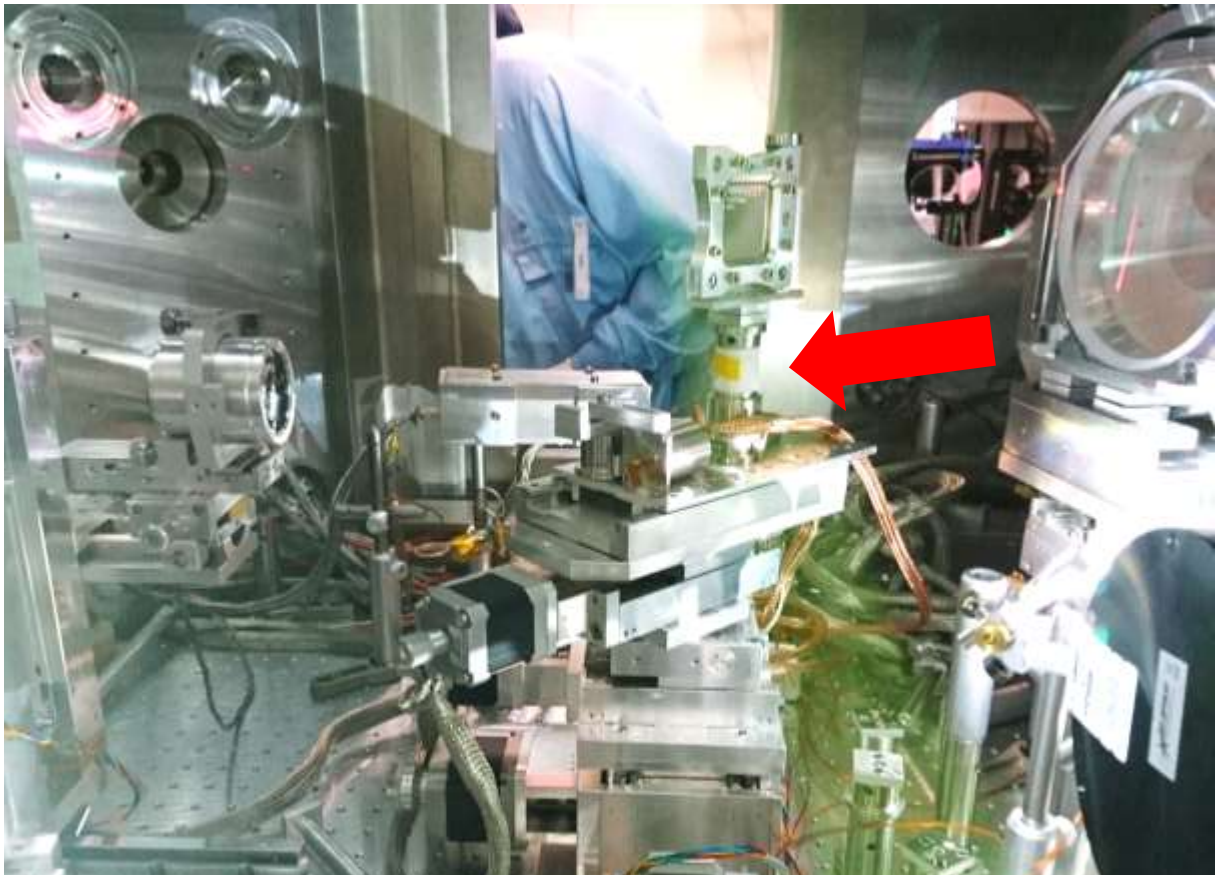



**Designed by C. Deiter, sample environment group**

Standardized design concept based on EUCALL project (#654220)

# EMP – ceramic insulation on target post

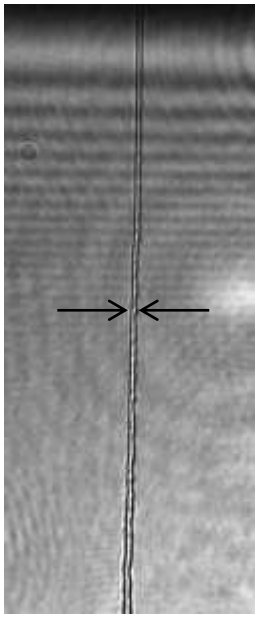


**first EMP tests of stages and motors in collaboration with DRACO team at HZDR**

# A catalogue of available cryogenic liquid jets

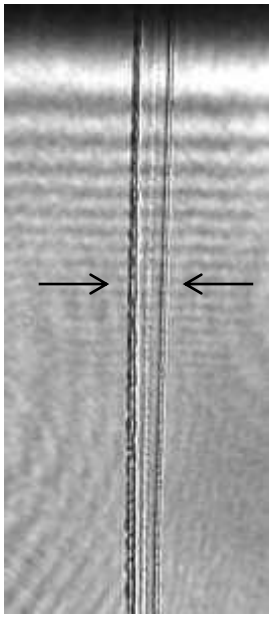
## Cylindrical Jet

2 -10 µm diameter



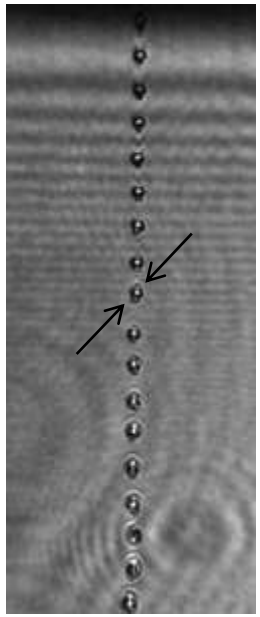
## Planar Jet

20 - 50 µm width, 0.3 - 4 µm thick



## Spherical Droplet Jet

10 - 19 µm diameter



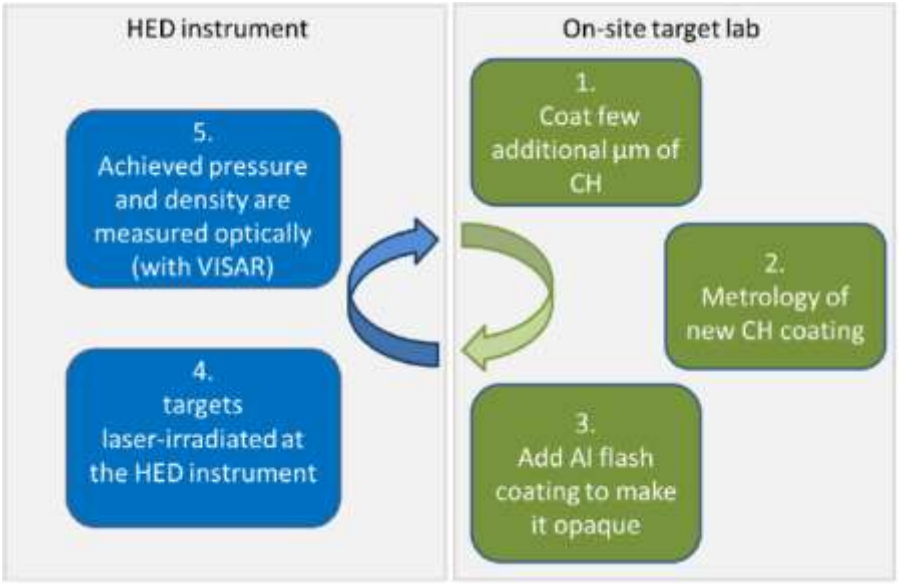
Courtesy of J. Kim (SLAC)

Performance of cylindrical jets using Deuterium, Methane ($CH_4$) and Argon successfully demonstrated

S. Goede, XFEL.EU

# Target fabrication lab

**HED will only reach 100% efficiency if users can, within hours or a day, modify and optimize their targets.**




- XFEL supports the establishment of an on-site target laboratory in upcoming XULAB building, ready by > 2021.
- DESY offers interim space from fall 2018, to have a basic target lab when x-ray commissioning starts at HED (February 2019).
- Personnel should be installed as the head of this lab, within XFEL "sample environment group". Synergies in metrology.
- We will define initial instrumentation asap.

# Thank you – recent photos from the HED instrument