HELMHOLTZ

<HMC>

RESEARCH FOR GRAND CHALLENGES

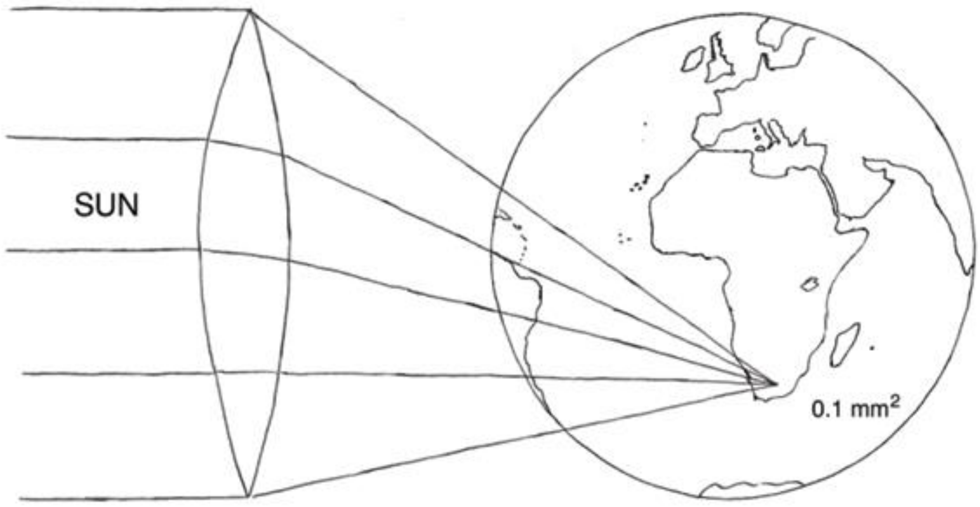
HELPMI: the Helmholtz Laser-Plasma Metadata Initiative

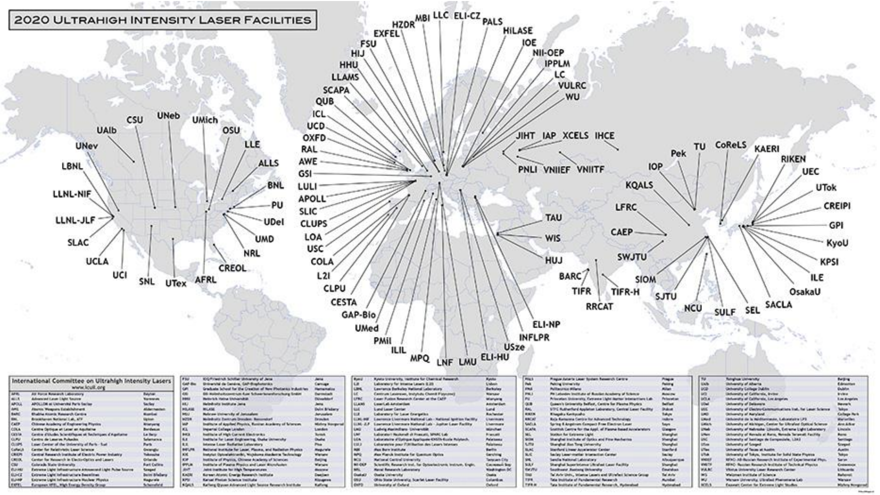
Start developing a data standard for the global LPA community

LPA Community

Lasers…

- Ultra-intense lasers can transform plasmas into particle-accelerating structures
  - Ultra-short (fs-ps), Joule-kJ laser facilties: high peak-power, ICUIL.org
  - Chirped pulse amplification (invented 1985, Nobel prize awarded 2018)





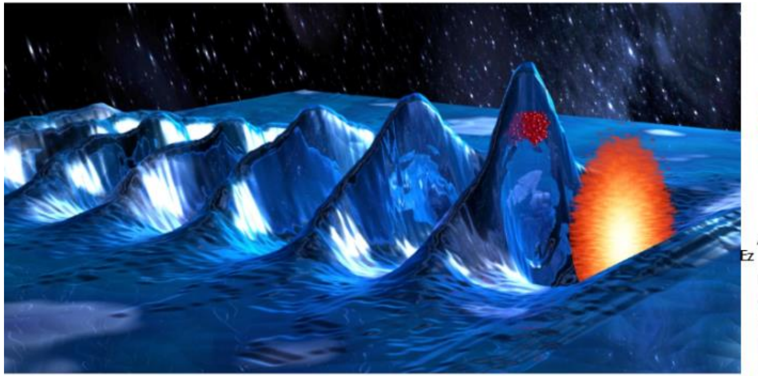
https://www.icuil.org/activities/laser-labs.html, [Interactive map]()

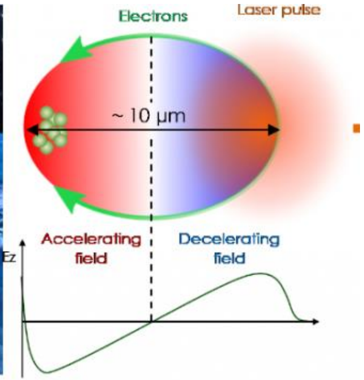
Schwoerer H. (2008). Particle acceleration with lasers. *S. Afr. J. Sci.* **104**, 299-304.

LPA Community

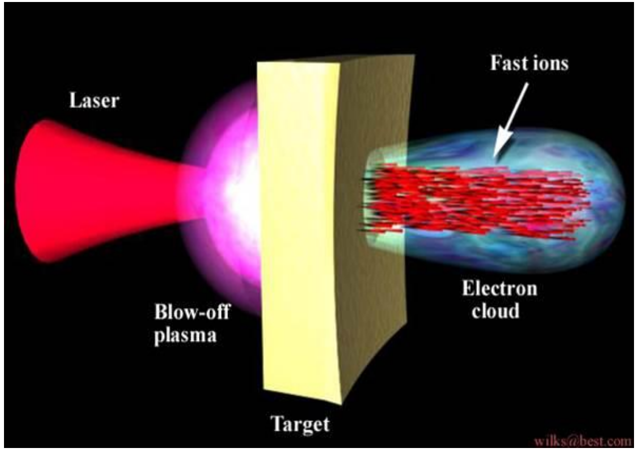
… and plasma accelerators

- Ultra-intense lasers can transform plasmas into particle-accelerating structures
  - Electron acceleration and ion acceleration in high gradients
  - Inherent ultra-short time structure and thus high peak currents





https://loa.ensta-paris.fr/research/upx-research-group/laser-wakefield-acceleration-lwfa/



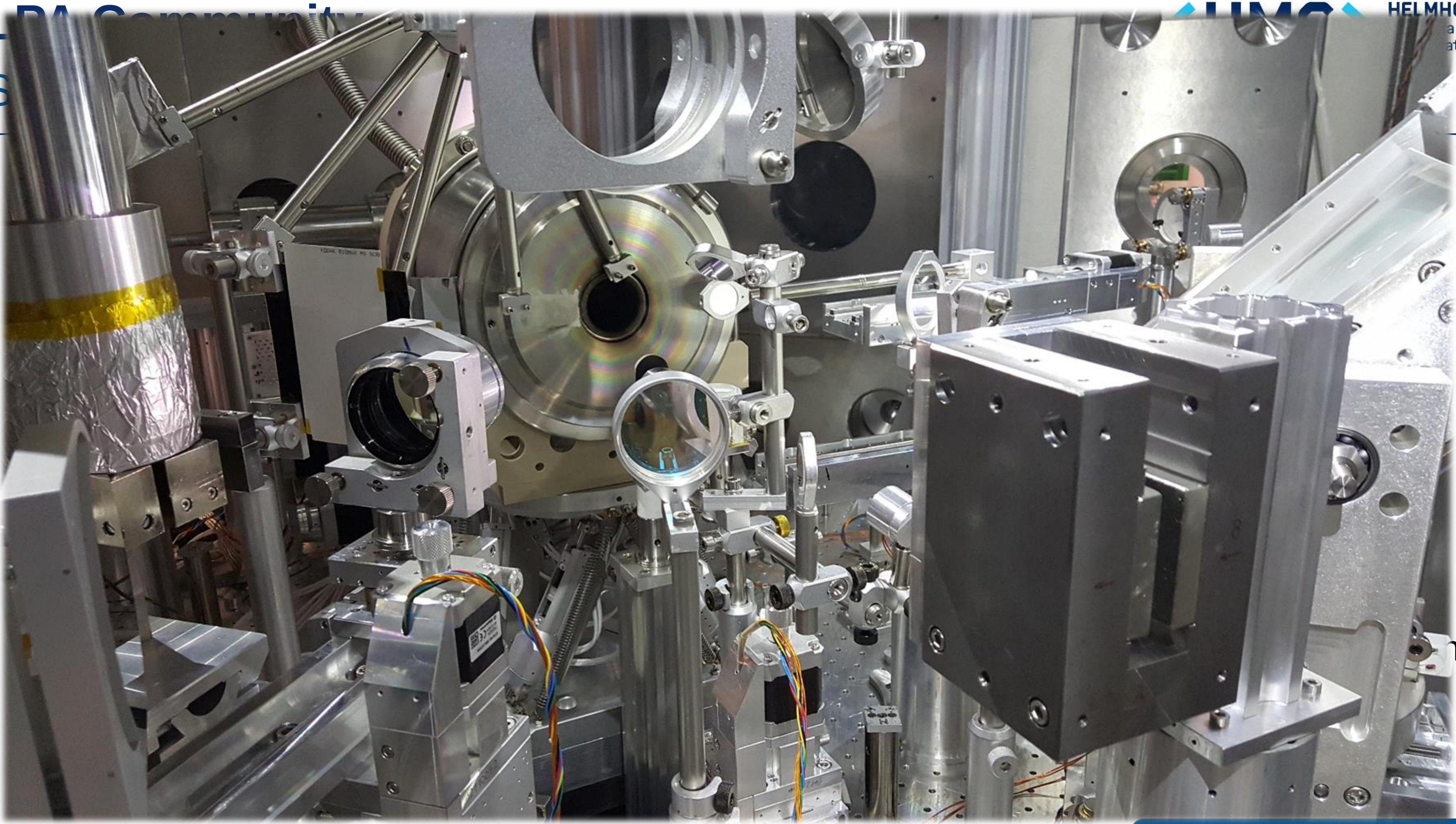
LPA Community

Science

- Ultra-intense lasers can transform plasmas into particle-accelerating structures
  - Accelerating structures are optically generated and transient
- Fundamental research focusing onto scalings, specific regimes and adequate control
  - Experimental studies in uncharted terrain: explorative, innovative
  - Numerical modelling (digital twin / complement) crucial for micro-physical understanding
    - Expensive simulations up to exascale computing, GPU-accelerated
  - Data-driven techniques are attractive due to complexity of LPA processes
- Applications
  - Small-scale accelerator substitute (Nuclear physics, Radiation physics, Medical research)
  - Secondary radiation sources (X-rays, g-rays, Neutrons, Free-electron lasers), fusion energy research

LPA Community

S



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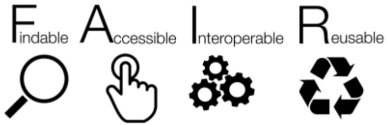
HELPMI: Main Goals

2-year project, 3 partner centers, 200k add. funding

- Initiative: **start** the development of a data standard for LPA experiments
  - Consulting and assistance from HMC community
  - Concepts, tools, trends, best practices, lessons learned…



- **Adopt** NeXus standard from PaN experimental community
  - Use existing base classes, possibly define new ones
  - Propose application definition

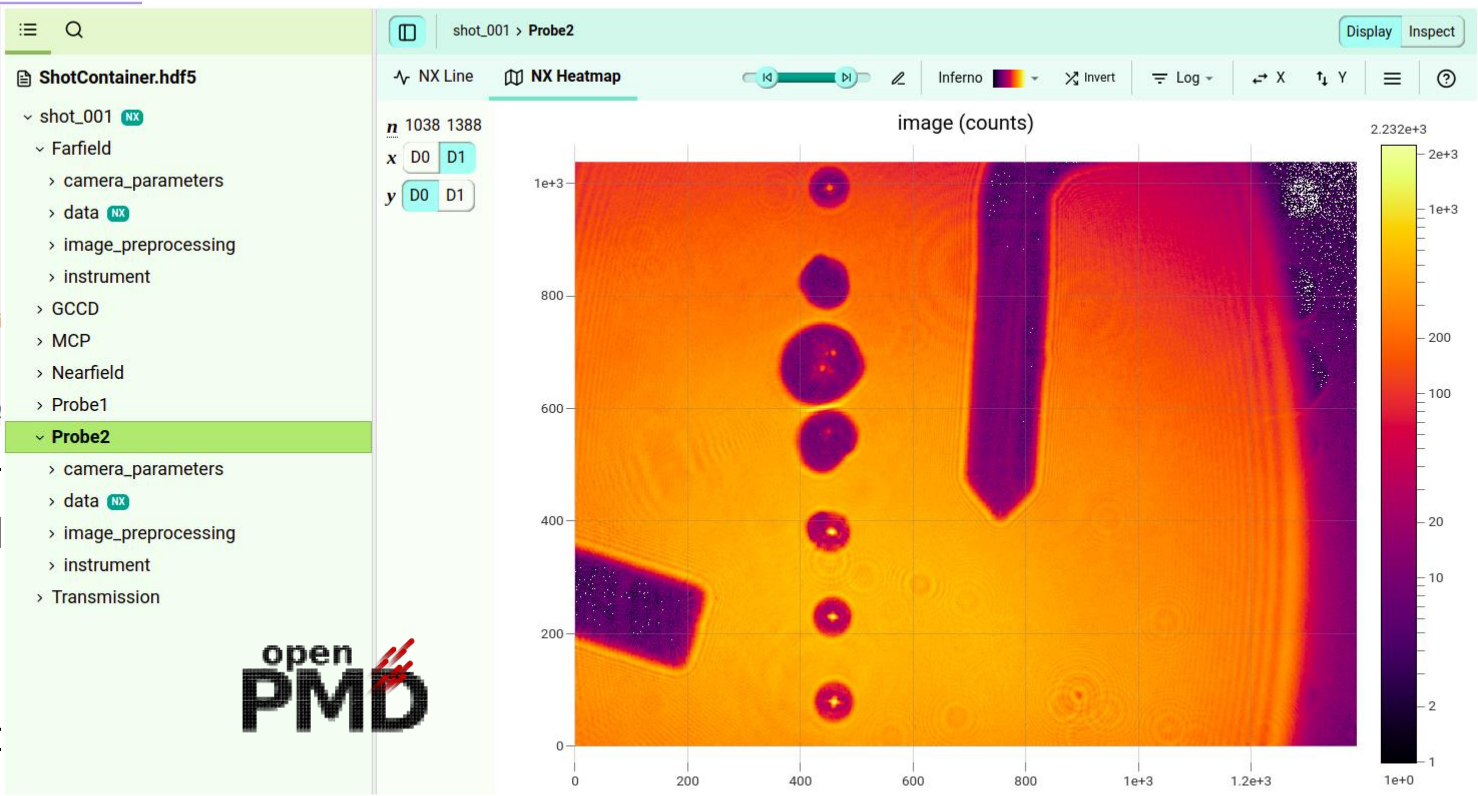
„an umbrella over a family of standards

- **Extend** the openPMD standard and API for arbitrary hierarchi
  - Currently established for simulations in LPA community
  - Fileformat-agnostic

Glossary: Domain-specific terms

HELPMI: example data set

Example data chunk to perform our trials



- Hierarchical stru
- Meta/Data in fol
- Files containing and experiment
- Setup models, c scripts

HELPMI: draft glossary

Devices-Detectors-Components-Library: https://doi.org/10.5281/zenodo.11143947

HELPMI Common Phrases/Categories

1. Technical Metadata
   a. Manufacturer or in-house design
   b. Model name/number
   c. Serial number
   d. Operating software and version number, dependencies (Win, Linux?, .NET?)
   e. Calibration data (Manufacturer)
   f. Last calibration date
   g. Pixel count in horizontal direction
   h. Pixel count in vertical direction
   i. Pixel size and/or pitch
   j. Noise measurement
   k. Technical drawing/file of device/setup
2. Procedural Metadata
   a. Name of detector/device as used in experiment
   b. Location of detector/device as used in experiment
   c. Schematic of detector's/device's setup
   d. Schematic of imaging/focusing setup
      i. Lens, objectives, filters, etc.
      ii. Imaging distances
   e. Custom calibration, Point Spread Function (PSF), Flatfield, Gainmap (links to data)
   f. Exposure, Shutter mode (rolling/global)
   g. Gain
   h. Binning
   i. Trigger and Timing (Delay)
3. Security/Access Metadata
4. Data
   a. Input/output energy
   b. Input/output polarization
   c. Input/output FWHM beam diameter
   d. Input/output spectrum
   e. Input/output spectral FWHM
   f. Input/output central wavelength
   g. 2D array of pixel values

Template.....2
Feedback.....3
Detectors.....3
Standard CCD/CMOS.....3
Focus Diagnostic.....4
Wavefront Sensor.....4
Gateable CCD.....5
Streak Camera.....6
Spectrometer – Photon.....6
Spectrometer – Electron.....7
Spectrometer – Proton/Ion.....8
Thomson Parabola Spectrometer.....8
Wizzler.....9
Dazzler.....10
SPIDER.....10
FROG.....11
2nd Order Autocorrelator.....12
2nd Order Autocorrelator for Measurement of Pulse Front Tilt, e.g., TiPa from Light Conversion.....12
3rd Order Autocorrelator (Sequoia, Tundra).....13
Scintillator Screen (electron pointing diagnostic).....13
Temperature Sensor.....13
Vibration Sensor.....14
Humidity Sensor.....14
Photodiode.....14
Quadrant Detector.....15
Vacuum Sensor.....15
Devices.....15
Linear Motor Stage (stepper, piezo, etc.).....15
Rotation Stage.....16
Mechanical Shutter (only template).....16
Electro-Optical Shutter (only template).....17
Spatial Filter.....17
Spectral Filter (only template).....18
Amplitude Filter (only template).....18
Polarizer Filter.....18
Beam Splitter (only template).....19
Generic Optic (only template).....19
Targets.....19

Partners and related projects

- openPMD: open Particle Mesh Data, open standard for PIC (and more)
- NeXus: system of standards from synchrotron and neutron facilities
- LASY.org: package for (standardized) laser pulse modelling in PIC simulations, can take measured data and uses openPMD format → add HELPMI terms
- plasma-MDS: simple schema, partly applicable to LPA, but completely new applications
- NEILS (network of extremely intense laser systems)
- ELI (European research infrastructure)
- THRILL (EU project on high-repetition rate lasers)

plasma-MDS @ LPA

Possible translation

- Source = Device which creates the plasma by ionizing the medium:
  - Laser system/facility with all parameters
- Medium = Substance being ionized or activated by source:
  - Target
- Target = Substrate on which plasma acts
  - often none
- Diagnostics
  - Diagnostics of Source(Laser)
  - Diagnostics of Medium(Target)
  - Diagnostics of Plasma at all

Acknowledgements

- Contact us: helpmi@hzdr.de
- Contribute: Workshop @ GSI Nov 13/14
  - https://indico.gsi.de/e/helpmi-workshop-2023
  - Fall 2024: stay tuned
- Some slides were inspired by
  - S. Brockhauser @ FAIRmat Tutorial #6 on Metadata standarisation
  - B. Watts @ HDF5 and Nexus

Who is HELPMI?

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