

# The Seismic Network for Accelerators

...hearing with thousand ears...

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WAVE workshop , May 13, 2025



## 1 DAS Network 2024

- DAS Interrogator
- DESY Campus
- Achievements
- PETRA

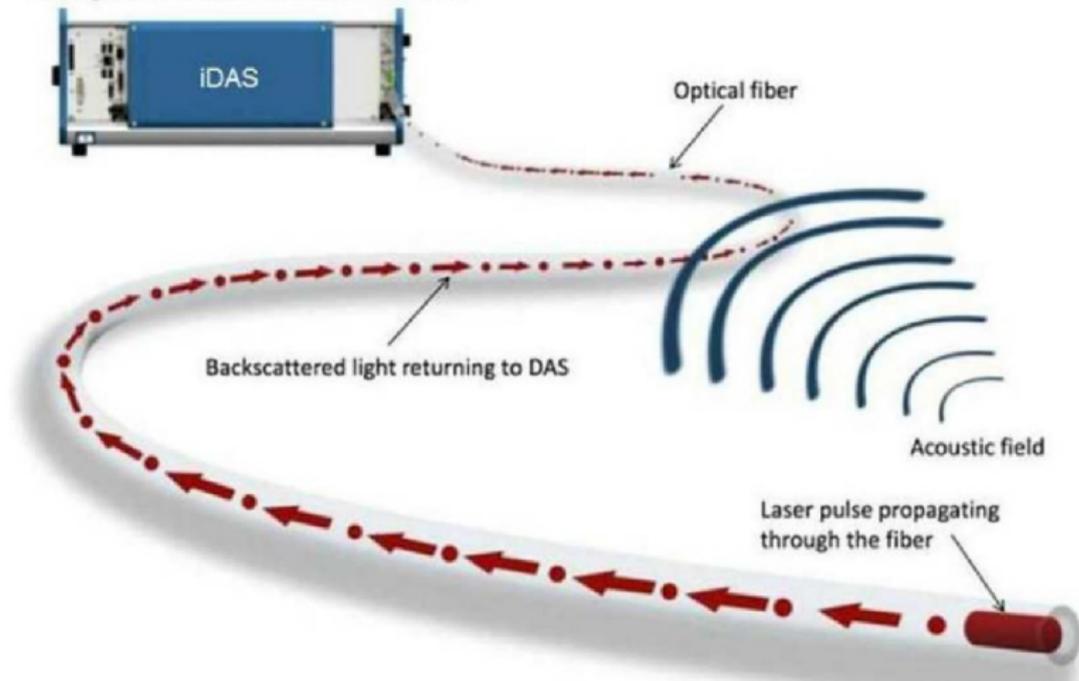
## 2 DAS Network 2025

- XFEL
- das-localize

## 3 New Ideas and What's next

# DAS Principle

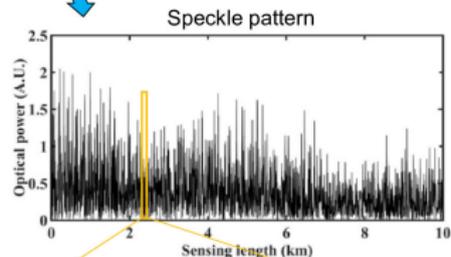
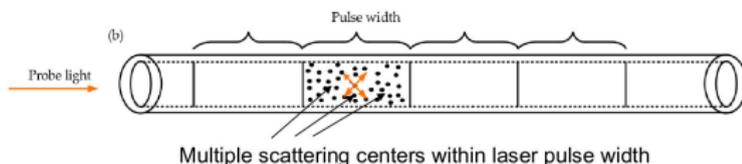
intelligent Distributed Acoustic Sensor



# Phase-sensitive Optical Time Domain Reflectometry

## Measurement principle...

### Multiple scattering centers & measured waveforms

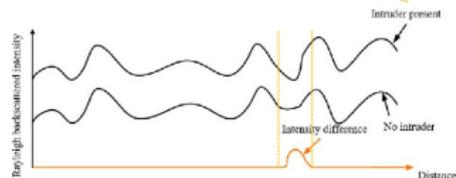
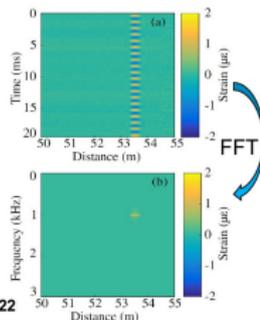


### Intrinsically requires large data rates...

z: sampling of reflection  $\sim 100 - 1000$  MSPS  
(SNR & spatial resolution)

t: laser pulse rep. rate  $\sim 1 - 100$  kHz  
(SNR & noise frequency resolution)

- Quickly  $\sim 1$  Gbyte/sec
- Data processing & analysis



Optics Letters · July 2020 DOI: 10.1364/OL.395922

DESY | Distributed fiber sensors | A. Lindner, N. Meyners, H. Schlarb | DESY | DIR-Meeting 04.02.2021

Sensors 2019, 19, 1709; doi:10.3390/s19071709

## Typical Parameter set

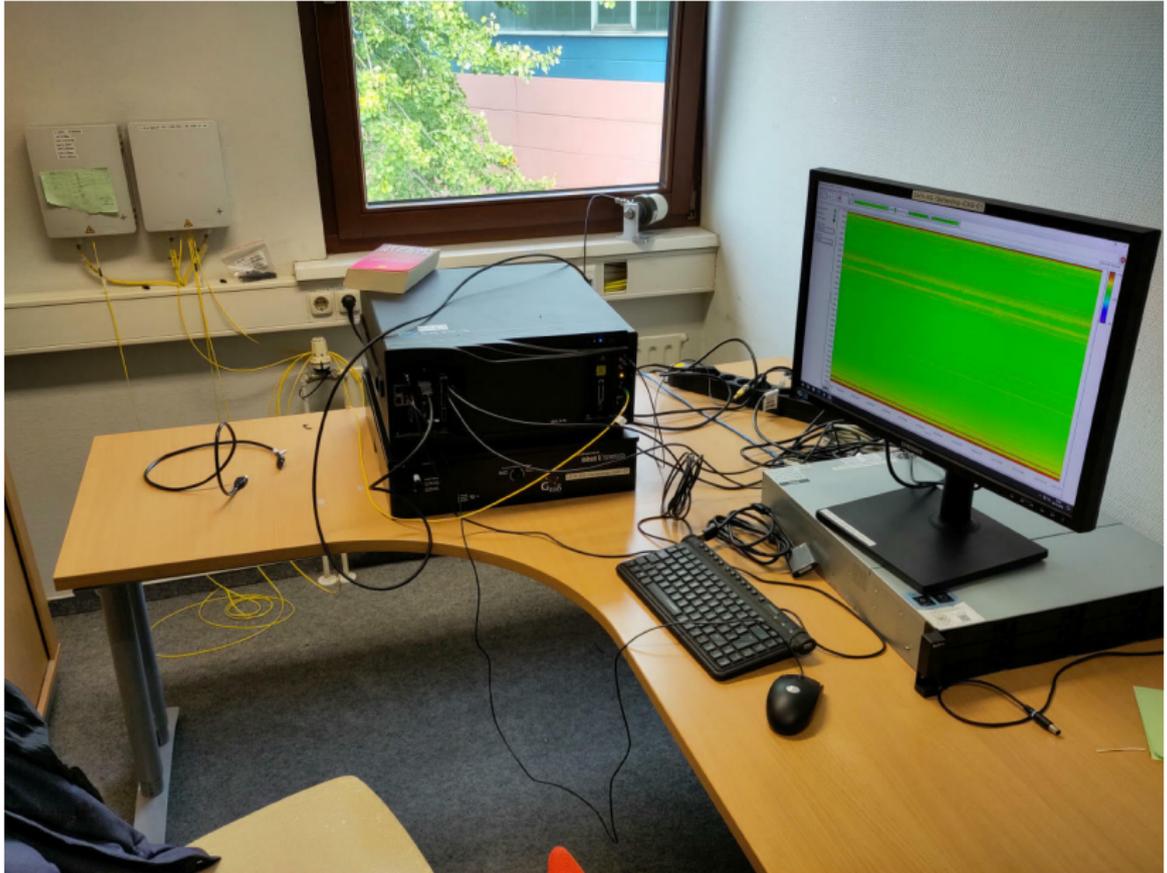
- Laser pulse width: 10 – 40 ns (at  $\lambda = 1550$  nm)
- Fiber length: 15.6 km (with a single instrument)
- Spatial sampling/resolution: 1 m / 10 m (gauge length)
- Time sampling/resolution 1000 Hz (Laser pulse rate)
- Frequency resolution  $< 0.01$  Hz (near DC) to 500 Hz

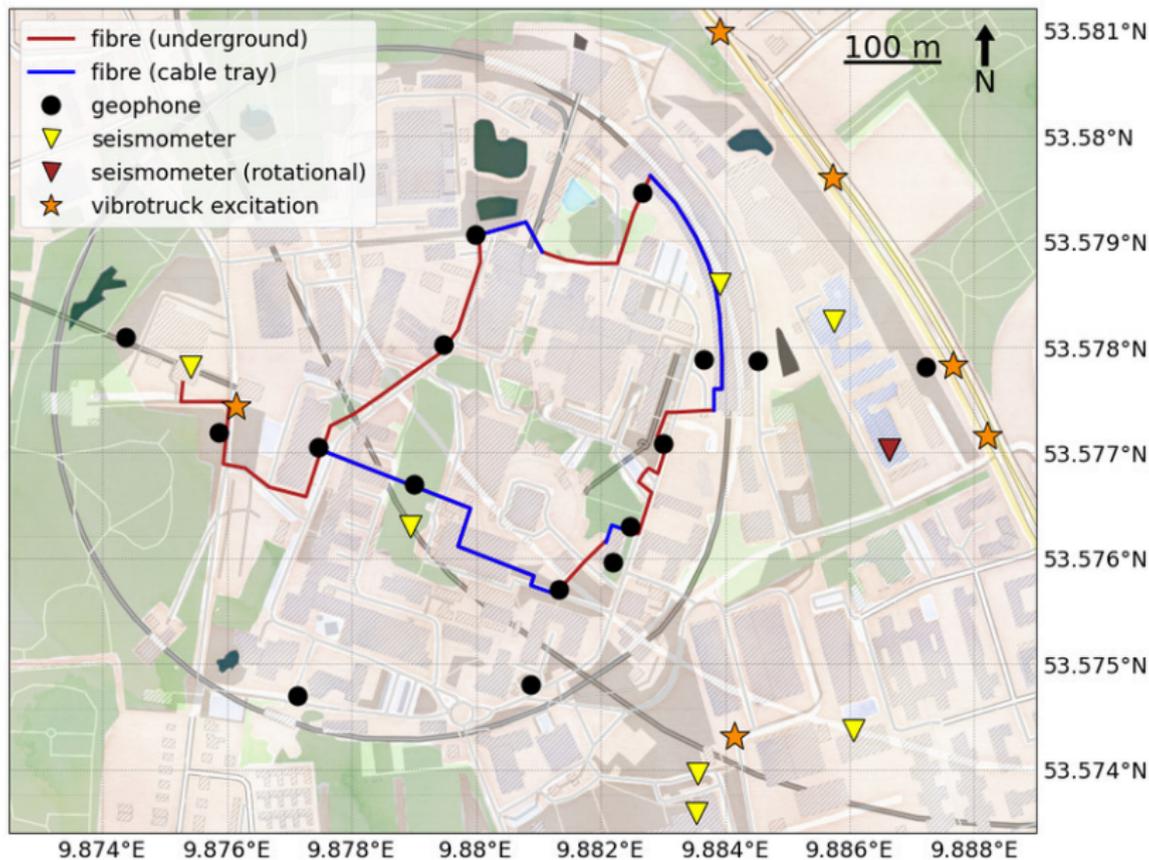
## What is the data about?

### Observables

- strain / nano strain (change in optical length)
- strain rate
- noise (seismic and acoustic)
- temperature / temperature change (from slow drifts)

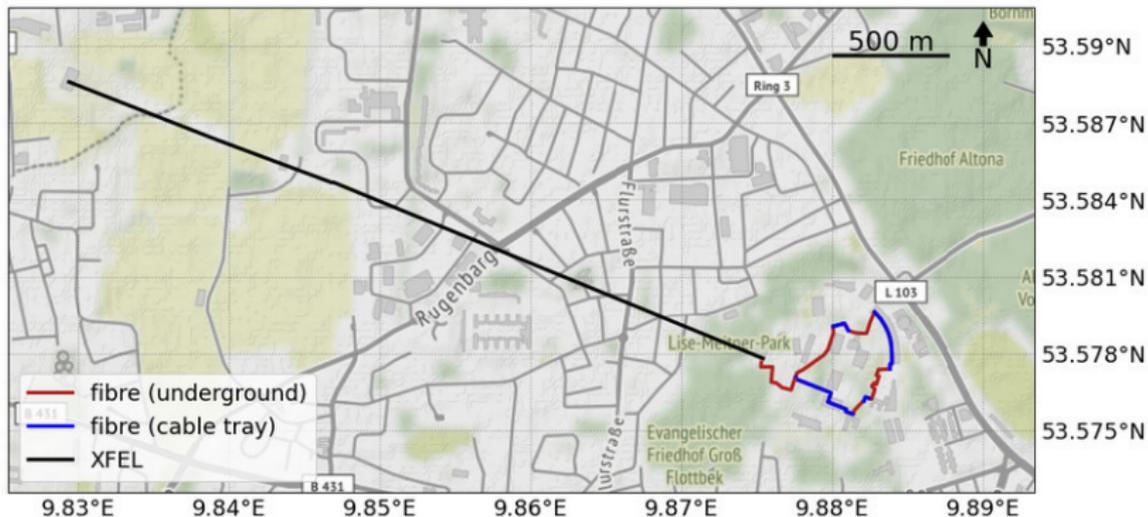
DAS Interrogator





DESY Campus

# DAS sensing: DESY Campus and XFEL

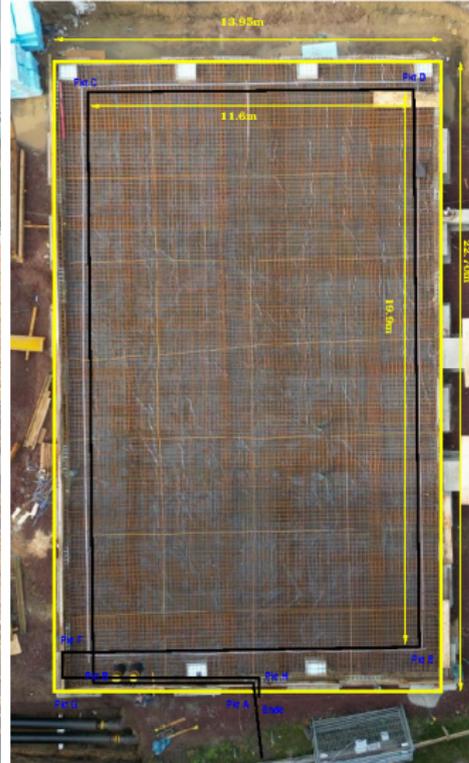


## DAS Network Achievements 2024 Campus Bahrenfeld/DESY

- 1 Extension of the fiber in foundation of Hall 54b.
- 2 2.5 km extension of the fiber in PETRA ring tunnel.
- 3 The Interrogator has moved from Bld. 35 to Bld. 55A.
- 4 We made a full new geo referencing of the fiber path.
- 5 Improved the algorithms for offline-analysis.
- 6 Quick data path for live visualization.
- 7 Databrowser and live visualization on a Server. (for outreach)
- 8 New Cross Spectral Density analysis of the signals.
- 9 ErUM-WAVE collaboration.
- 10 The fiber cable in concrete founding was destroyed.
- 11 Investigations/Setup in MOCKUP tunnel for fiber and installation types.

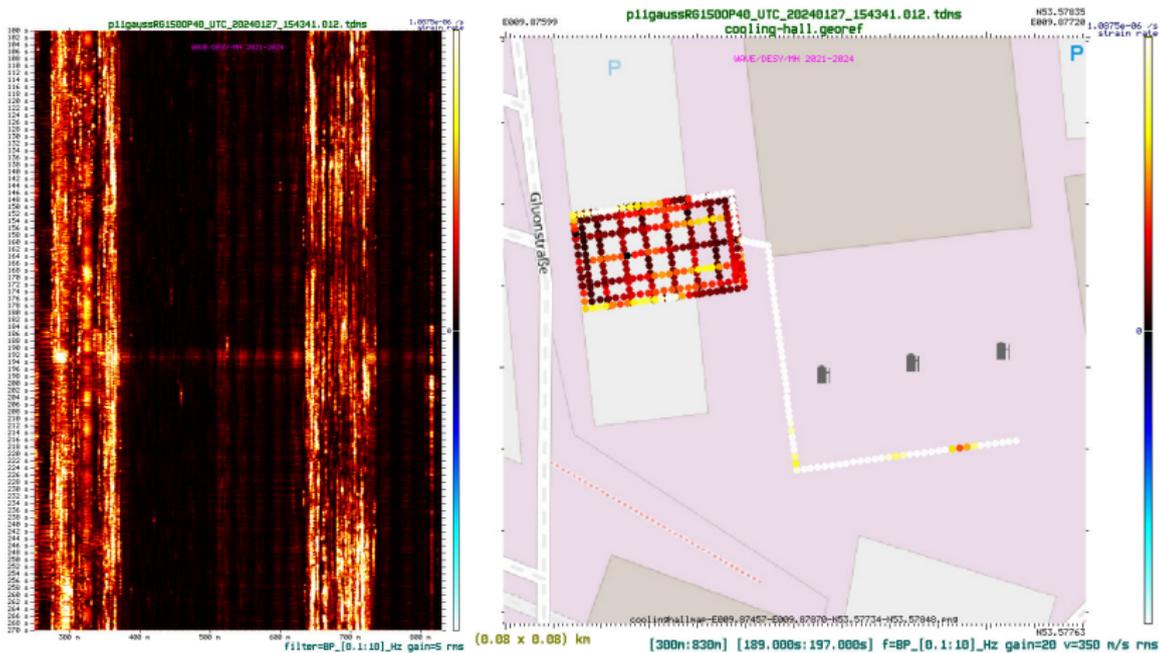
Achievements

# Fiber cable in Foundation of Building 54b



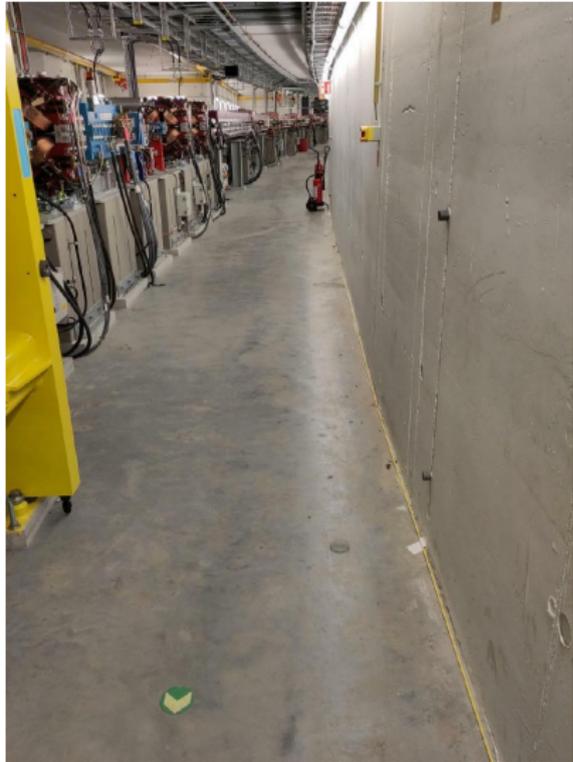
## Achievements

## Sinkhole Event 27 Jan 2024 Jänisch-Park



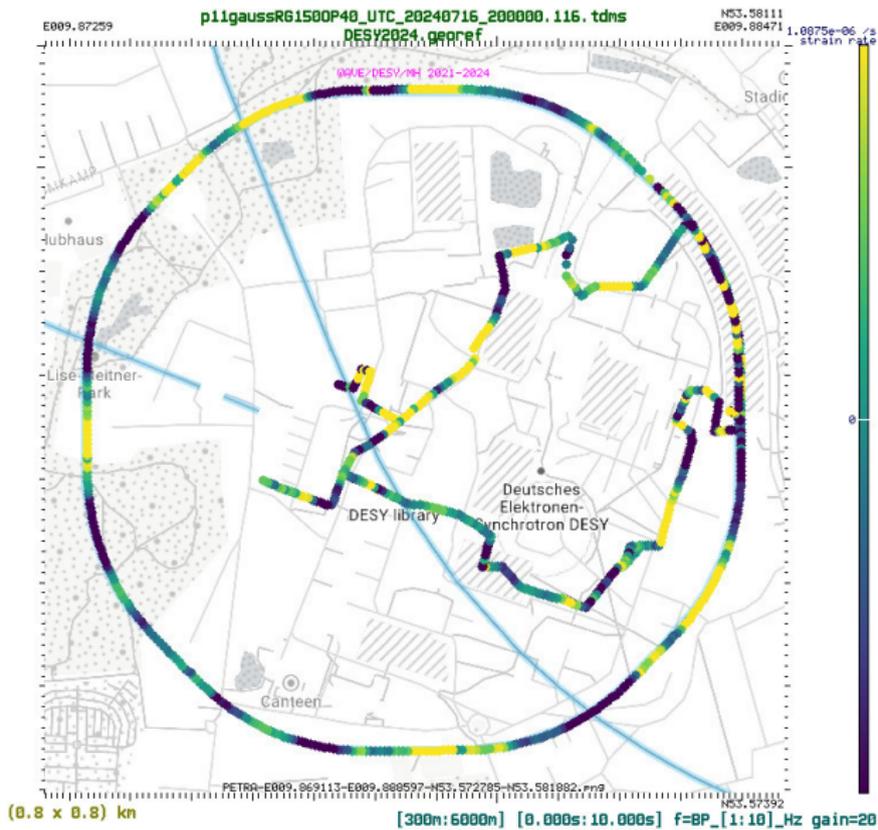
PETRA

# Fiber cable in PETRA

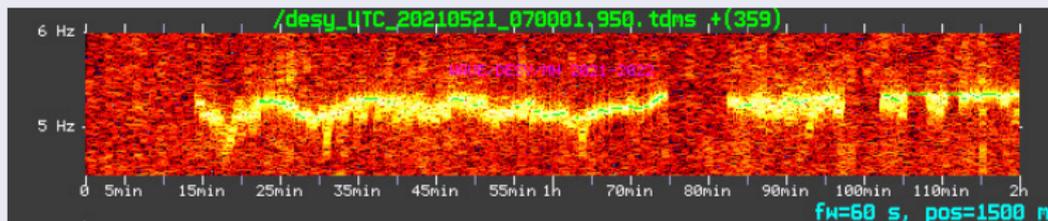


PETRA

## New fiber cable in PETRA



## Solved: 5.2 Hz seen at PETRA

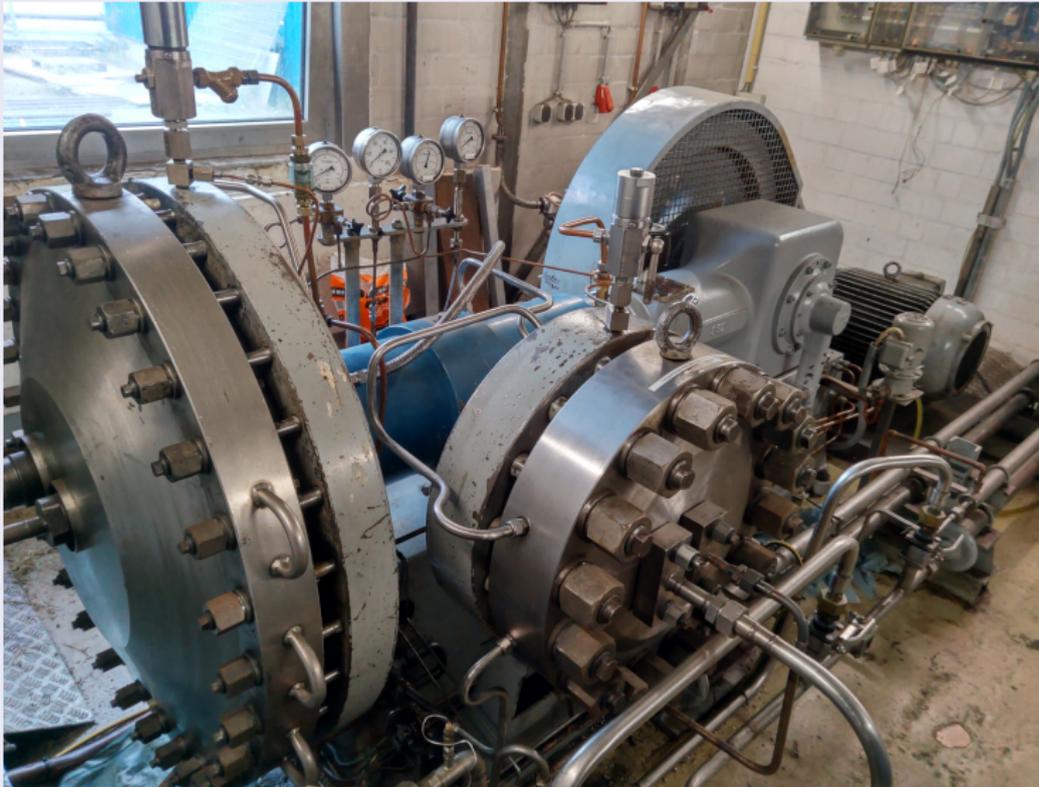


long time unsolved puzzle:

- Disturbs the PETRA closed orbit (feedback),
- very narrow bandwidth
- irregular occurrence,
- seen everywhere on the campus.

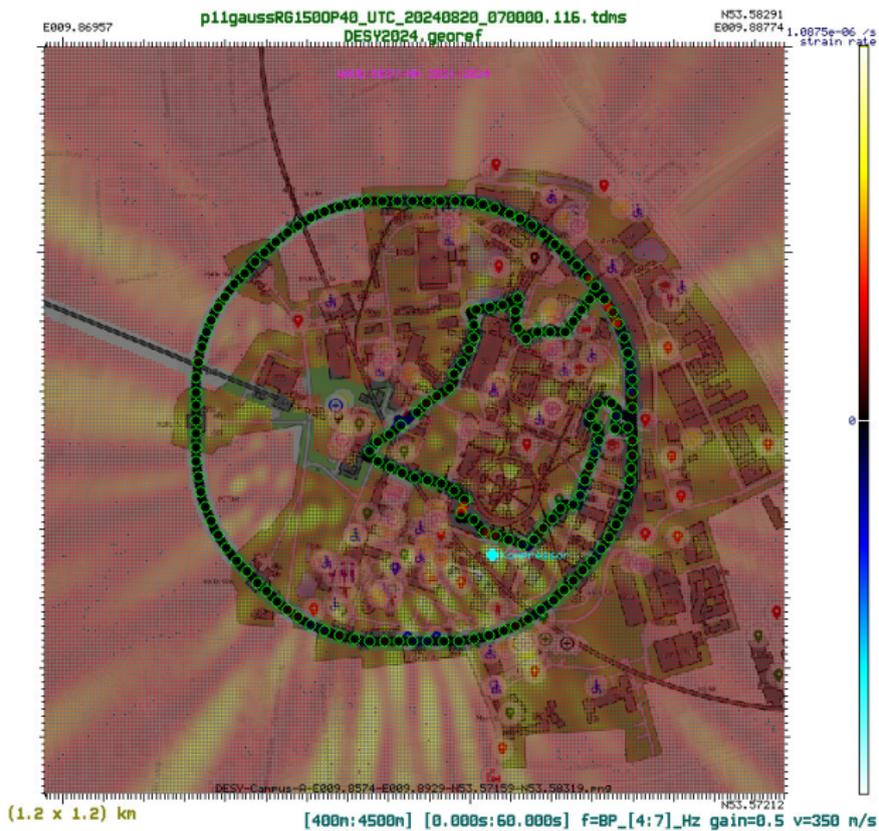
→ disturber has been found.

## The 1965 Helium-Compressor



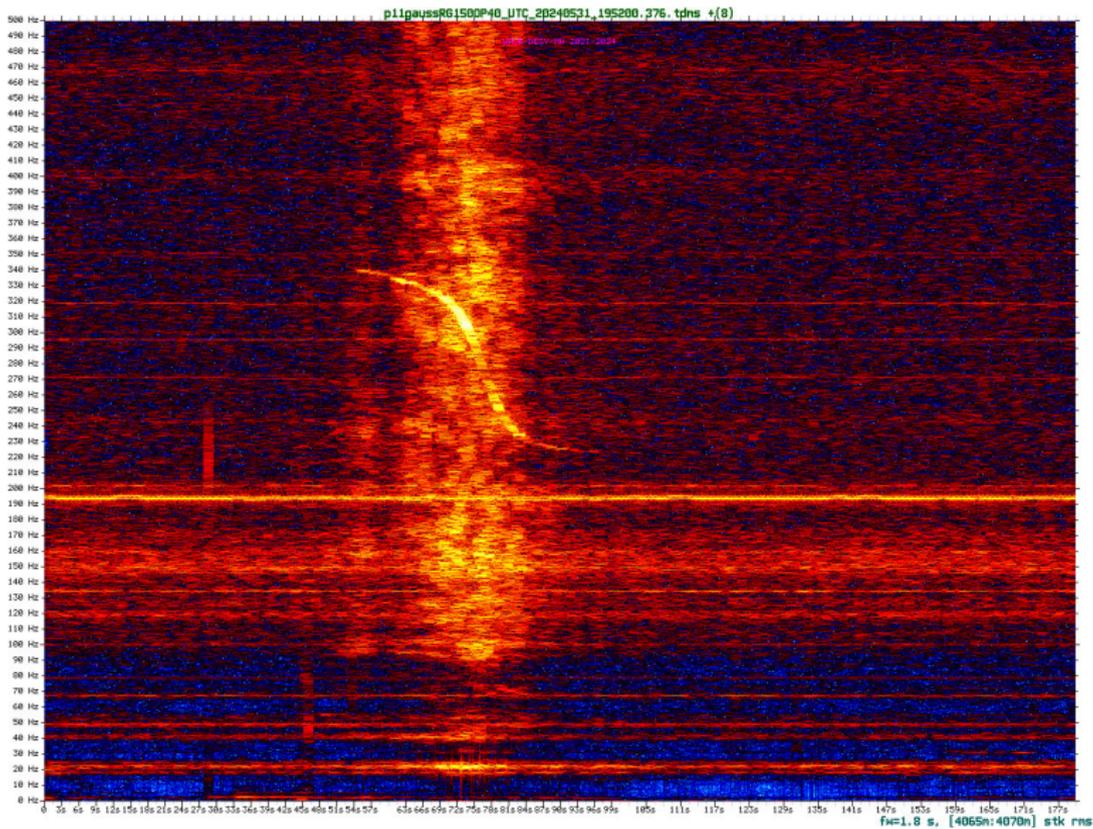
PETRA

# Reconstruction of waves from data



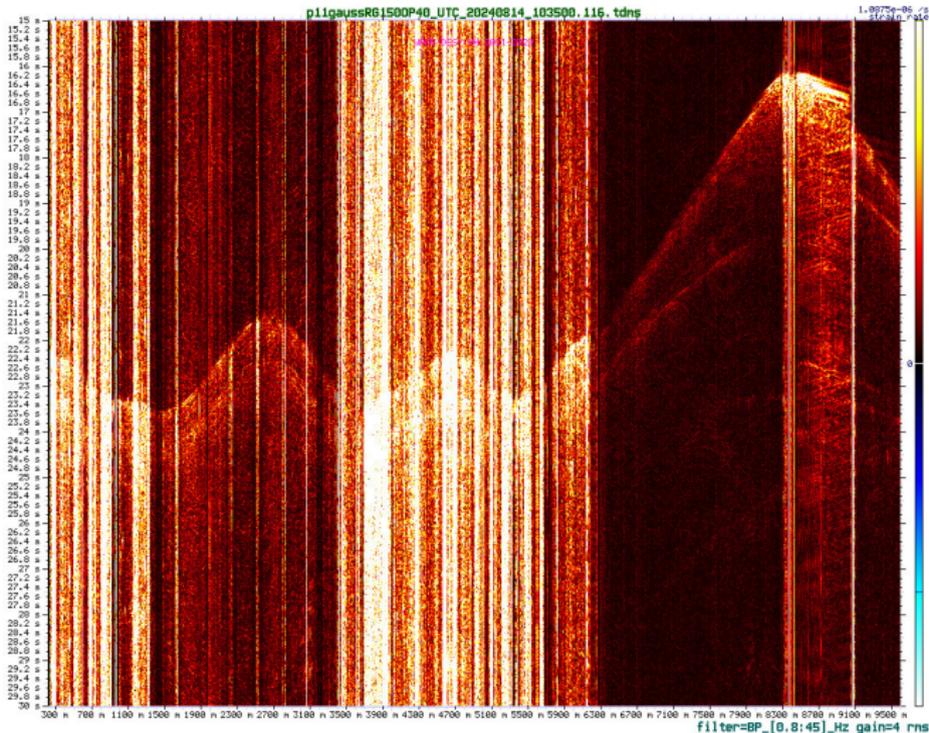
PETRA

# Airplane signatures



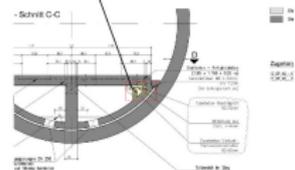
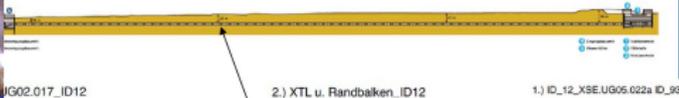
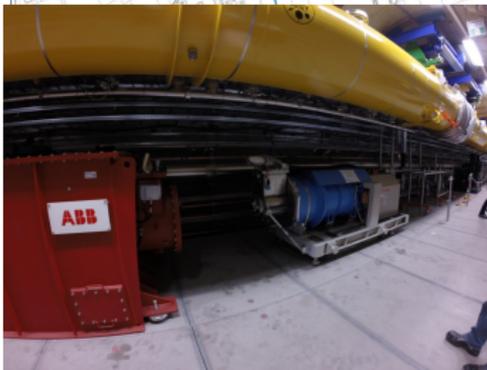
PETRA

# Thunderstorms



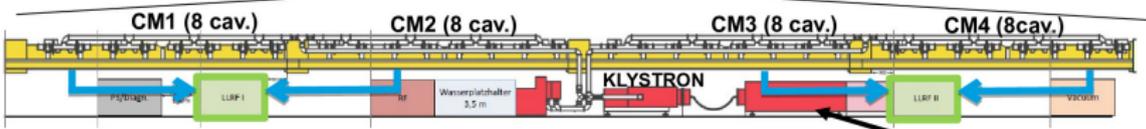
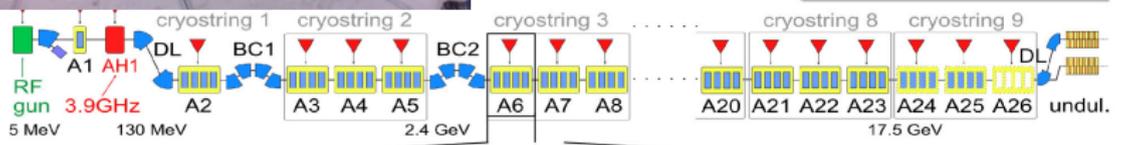
## The Movies

- **Lightening 1** (lighteningwave1b.webm)
- **Lightening 2** (lighteningwave2.webm)



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LINAC3



XFEL

# Proposal for XFEL

## proposed fiber layout

XHEXP

2100m XTIN+XTL

1200m XTD2+XTD9

1300m XTD10+XTD4+XTD2

1200m XTD1+XTD6

1000m XTD7+XTD3

1000m XTD3+XTD8

total &lt; 20km

XSIN

XTIN

XTL

UG7

carpus

interrogator

XTD1

XTD6

XTD7

XTD5

XTD3

XTD8

XTD2

XTD9

XTD4

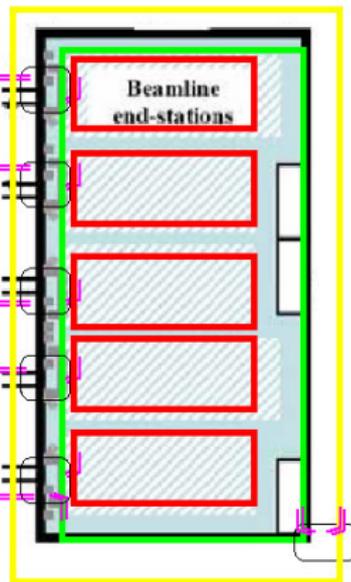
XTD10

Beamline  
end-stations

300m in soil

300m inside XHEXP

4x120m hutches



## Work to be done

### Hardware Installation

- Install cables,
- get and set up interrogator.
- Geo-Referencing of the new fibers.
- integrate into science city network.

### Software

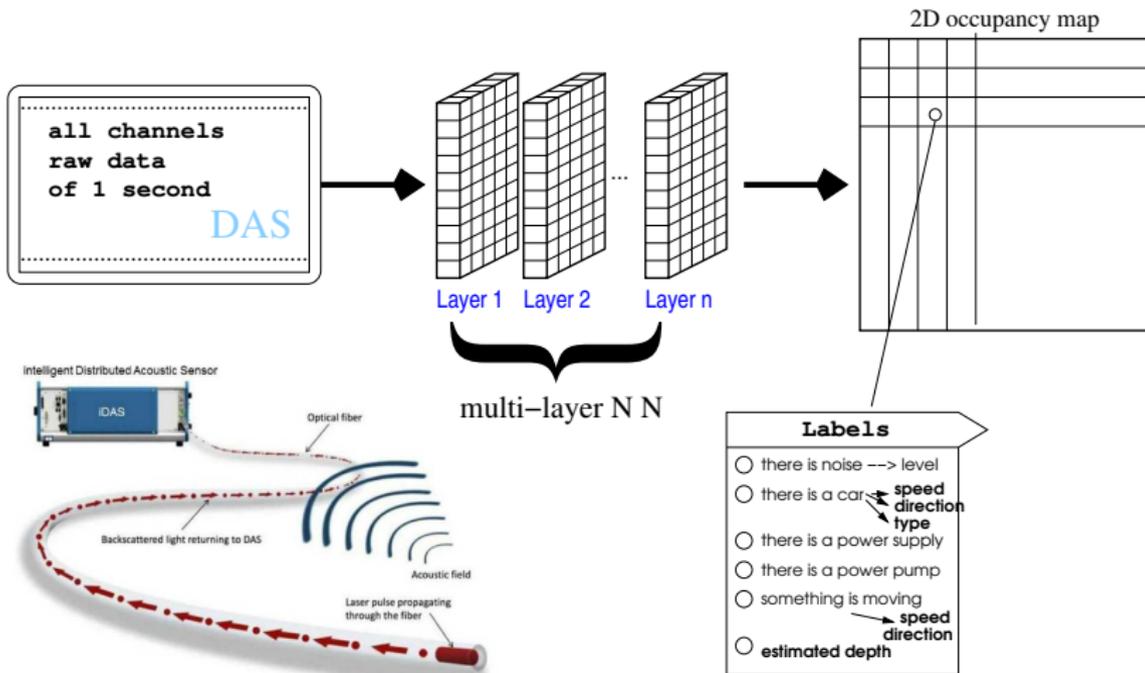
- Data flow handling, processing, storage.
- Visualization of the data.
- Integration into accelerator control systems.

→ Nearly all software and algorithms in house development.

das-localize

# Algorithmic project

(das-localize)



## My vision for 2025:

- 1 equip all (photon) tunnels of XFEL with cables on the tunnel floor (July)
- 2 Interrogator needs to move again(!) from Bld. 55A to Bld. 3.
- 3 Redo geo referencing of the new fiber cables paths.
- 4 Buy another Interrogator for XFEL (Sept).
- 5 Project: das-localize/ErUM-SESAM: localization and classifications of noise sources on a course grid using NN.
- 6 Project: Orbit and optics simulations for PETRA-IV using DAS data.
- 7 Project: **Wave field reconstruction** and prediction using DAS data (ErUM-WAVE), for which **properties of fiber** sensor needs to be measured, coupling factors, sensitivities, **comparisons with seismometer** data and cross-calibration, different fiber types, eliminating temperature effects, → Eriks Talk.

## Whats Next?

... to form the seismic network for Hamburg:

### Hardware

- Fiber cables in all new buildings + soil fibers around.
- Fibers in all accelerator tunnels + experimental halls (on the floor)
- additional fiber in (around) HERA ring tunnel (6.5 km)
- indoor-fiber in labs with cryo-electron microscopes (FS).

### Software

- real-time data processing and live disturbance visualization with ML
- wave predictions everywhere (ERUM WAVE) and localizations.
- Automatically **identify**, **classify**, and **localize** disturbances. Quantify and estimate impact on experiments.

## New Ideas

### Hardware

- "Dual-Use" of the DAS fiber: We can measure ionizing radiation in the accelerator tunnels using the fibers with a stationary OTDR Measurement device which we can permanently operate at one of the fibers in the tunnel and automatically readout.