

Industry

NAVIGATOR

SUSTAINABLE DEVELOPMENT
STRATEGIES FOR T&D

CONFERENCE 2025

Application of Fiber Optic Sensors for Transformer Testing PD Localization During FAT

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What to take home

Partial discharges, PD, during FAT can be localized

- Fast
- Accurate
- Reliable



Impact of PD on FAT and production process

Unpredictable delay

Simple case – PD source outside transformer

- Example: Pollution on bushings

< 8 hours delay

Complex case – PD source inside transformer

- Example: Issue in insulation

> 8 hours delay

Impact outside FAT in labor, resources and schedule



Partial Discharge detection

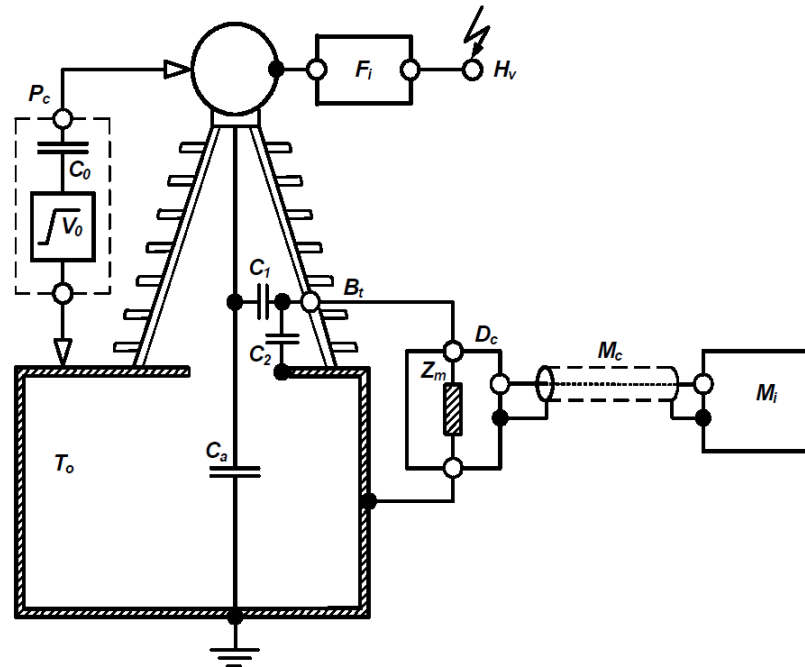
Electric quadrupoles

- Sensitive
- Industry standard
- Reliable
- Experience in interpretation

Be aware:

Apparent charge

IEEE Std C57.113-2010
IEEE Recommended Practice for Partial Discharge Measurement in
Liquid-Filled Power Transformers and Shunt Reactors



- C_0 – Calibrating capacitor
- C_1 – Capacitance between HV conductor and bushing tap
- C_2 – Capacitance between bushing tap and grounded bushing flange
- C_a – Virtual capacitance of the test object
- D_c – Coupling device
- F_i – Noise rejection filter
- H_v – Connection to the HV test supply
- M_c – Measuring cable
- M_i – Measuring instrument
- P_c – PD calibrator
- T_o – Test object
- V_0 – Step pulse generator
- Z_m – Measuring impedance

Figure 1—PD measuring circuit using the bushing tap coupling mode

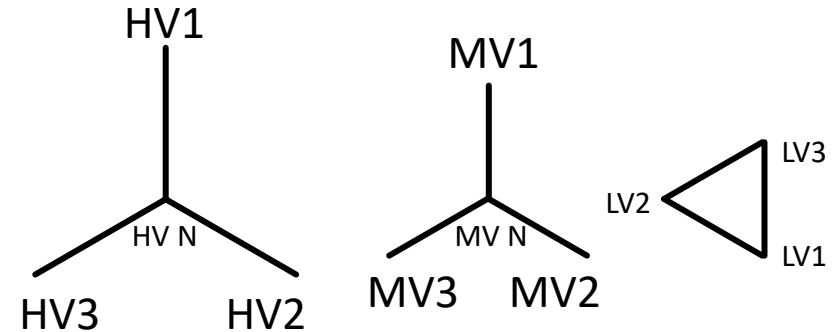
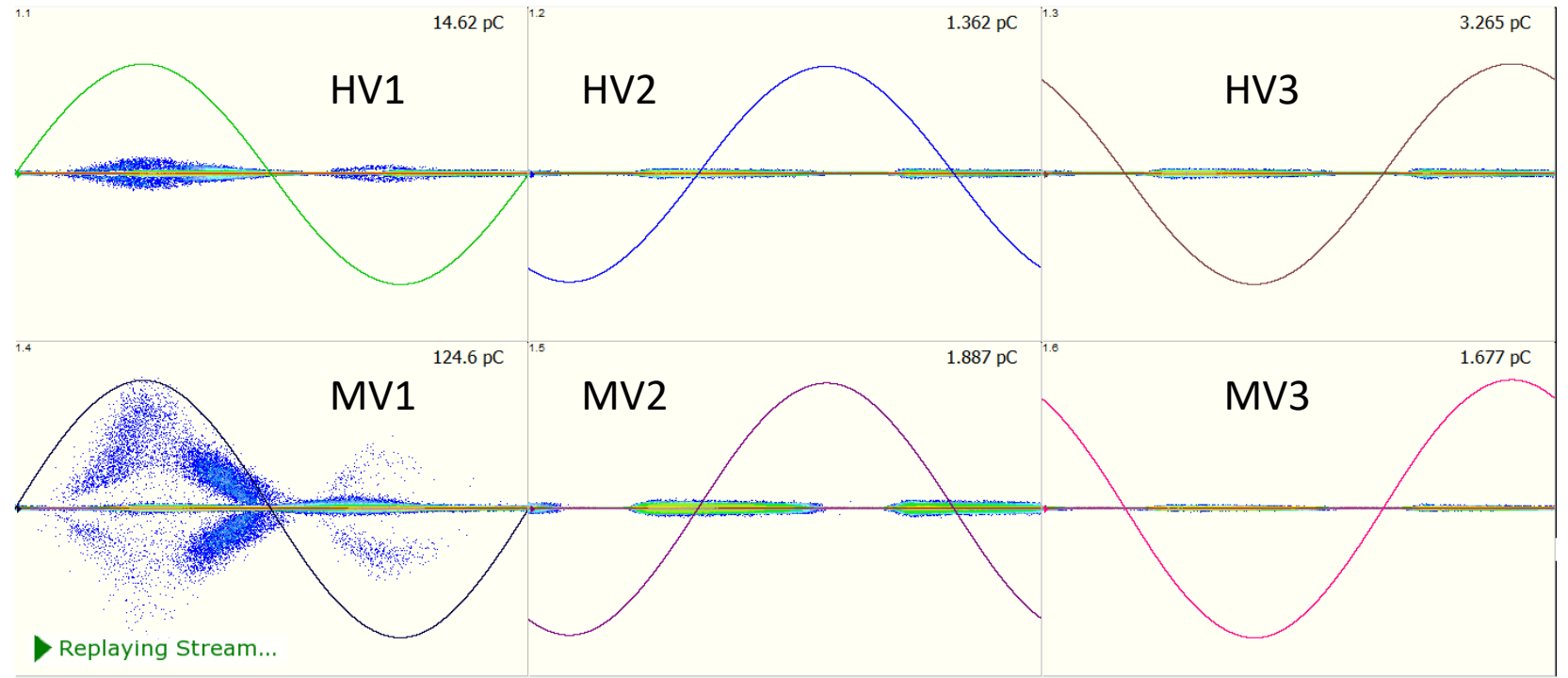


Partial Discharge issue during FAT

Example

- YNyn0d5
- PD on MV1
- Internal PD

Measure on other terminals

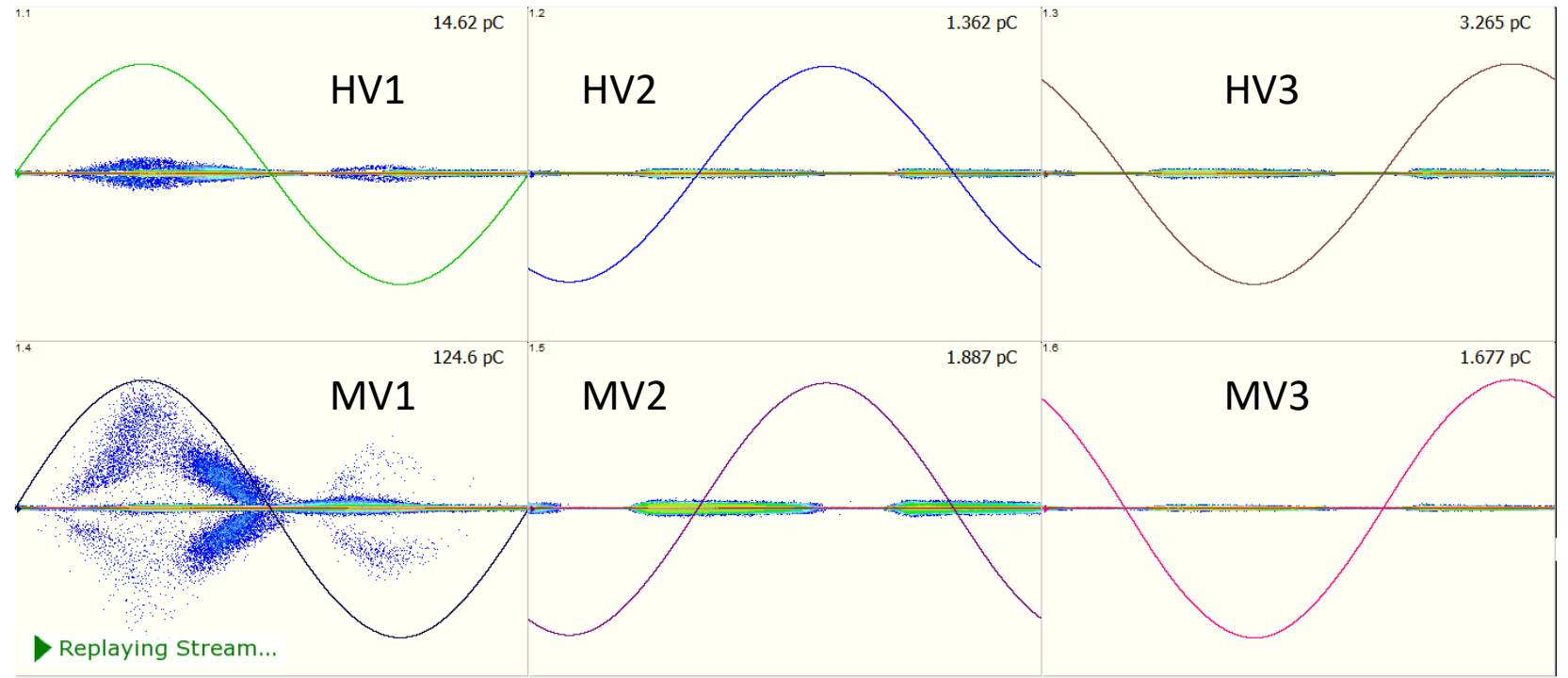
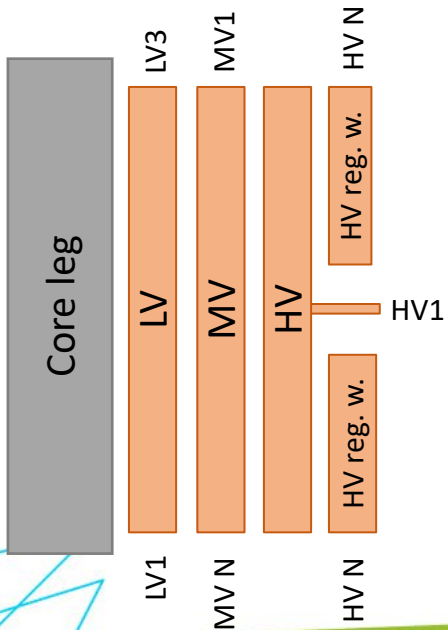


Coarse PD localization

Example

- YNyn0d5
- PD on MV1
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Measure on other terminals

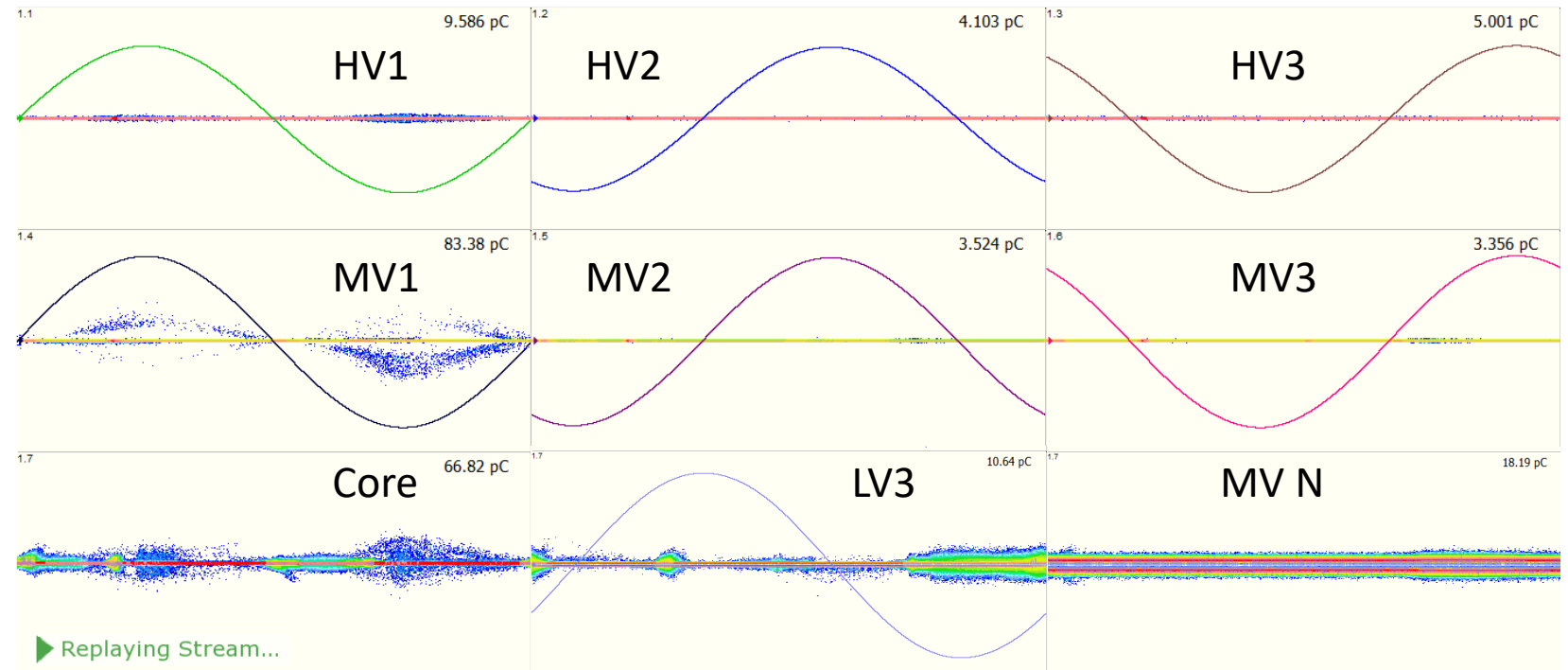
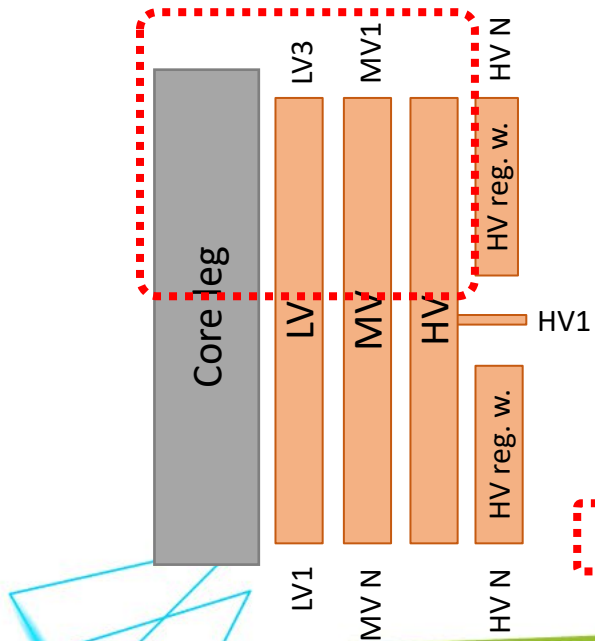


Coarse PD localization

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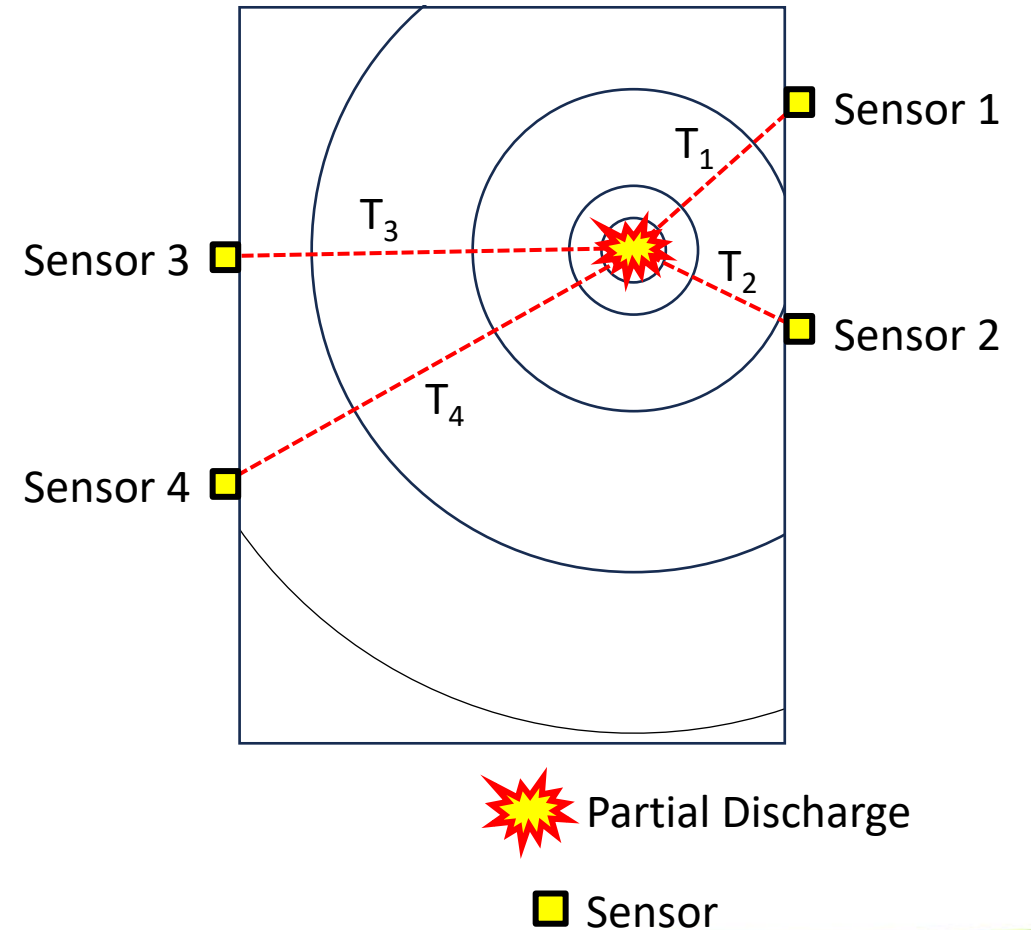
Measure on other terminals



Very difficult to find the actual partial discharge source in the transformer based on this information.
Internal inspection might not be successful

Improve accuracy - Acoustic localization

1. PD causes acoustic shockwave,
2. Shockwave reaches sensors,
3. PD location calculated based on *difference in time of arrival*.



Acoustic localization - Goal

1. Find location of PD fast → < 4 hours
2. Accurate localization of PD → +/- 15 cm
3. Clear information on PD location to the organization

Transformer PD Localization Report

Test information

Test date: 9/27/2024

Test time: 8:18 AM

Test leader: SV

Global Information

Order nr.:

Serial nr.:

Customer: customer

SW Version:2.4.18

Algorithm Version:1.0.0

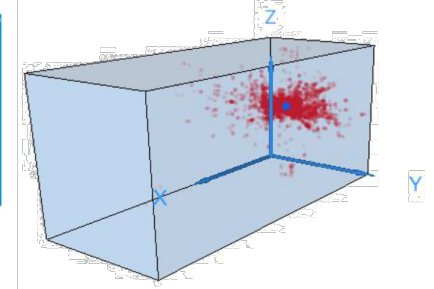
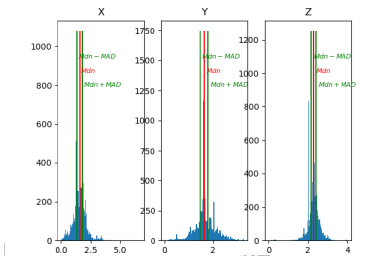
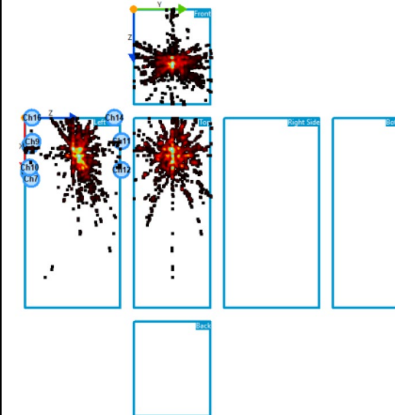
Notes:

Results:

X(m) = 1.5800 +/- 0.2159

Y(m) = 1.6350 +/- 0.1602

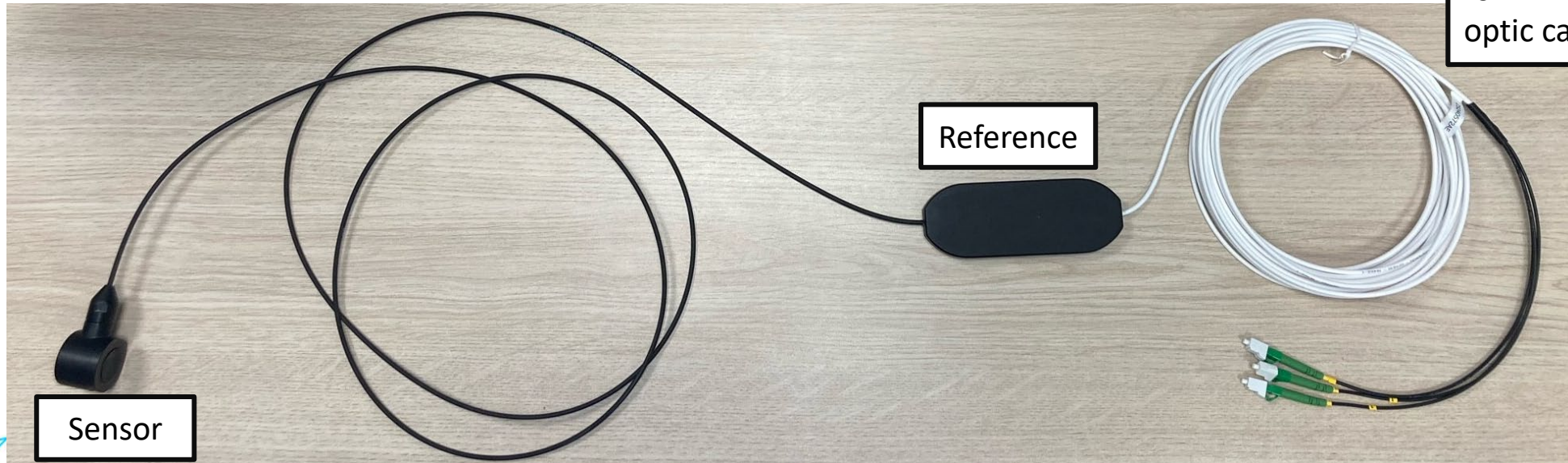
Z(m) = 2.2760 +/- 0.1207



Acoustic localization – Sensor

Optifender manufactured by OPTICS11

- Fully passive fiber optic sensors
- Up to 32 sensors
- EMC hard



Acoustic localization – Sensor

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Sensor top view



Sensor bottom view



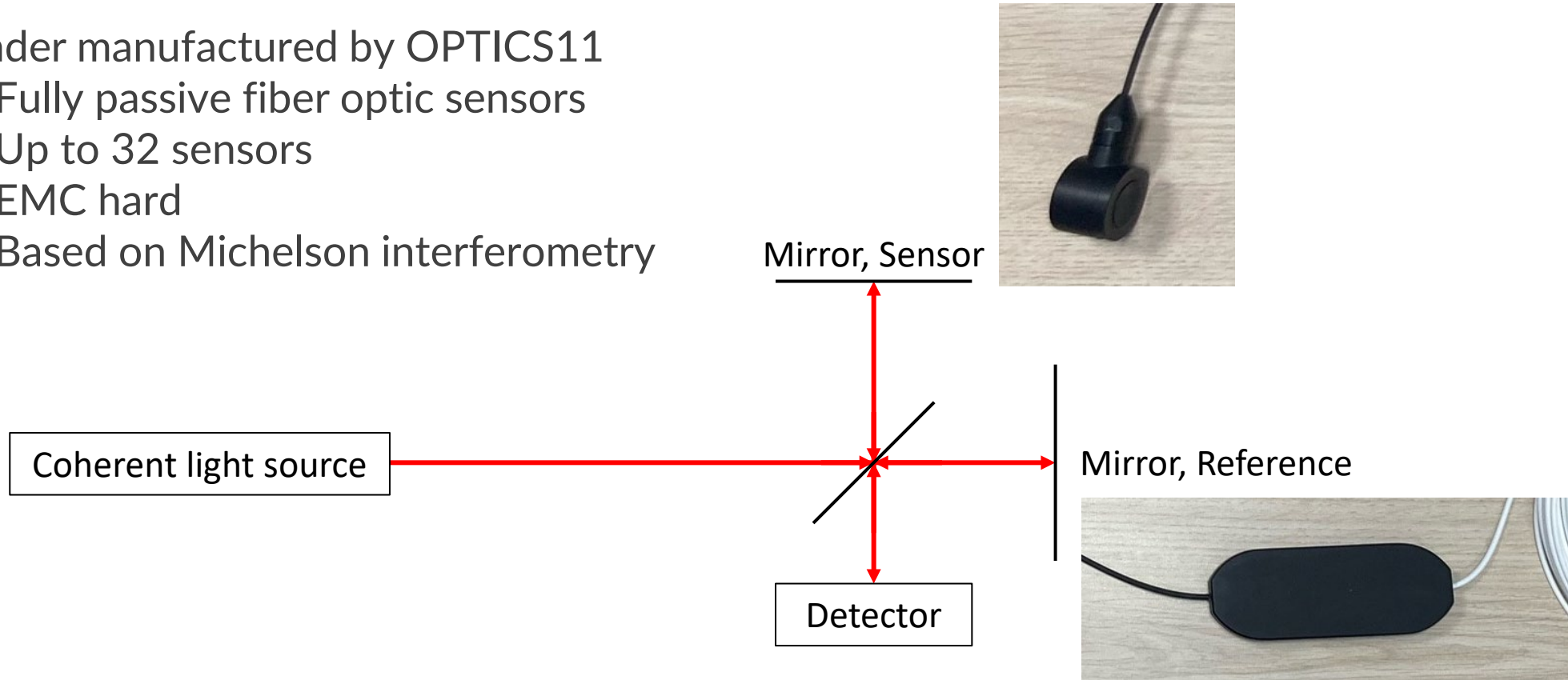
Sensor side view



Acoustic localization – Sensor

Optifender manufactured by OPTICS11

- Fully passive fiber optic sensors
- Up to 32 sensors
- EMC hard
- Based on Michelson interferometry



Acoustic localization – Sensor mounting

Optifender manufactured by OPTICS11

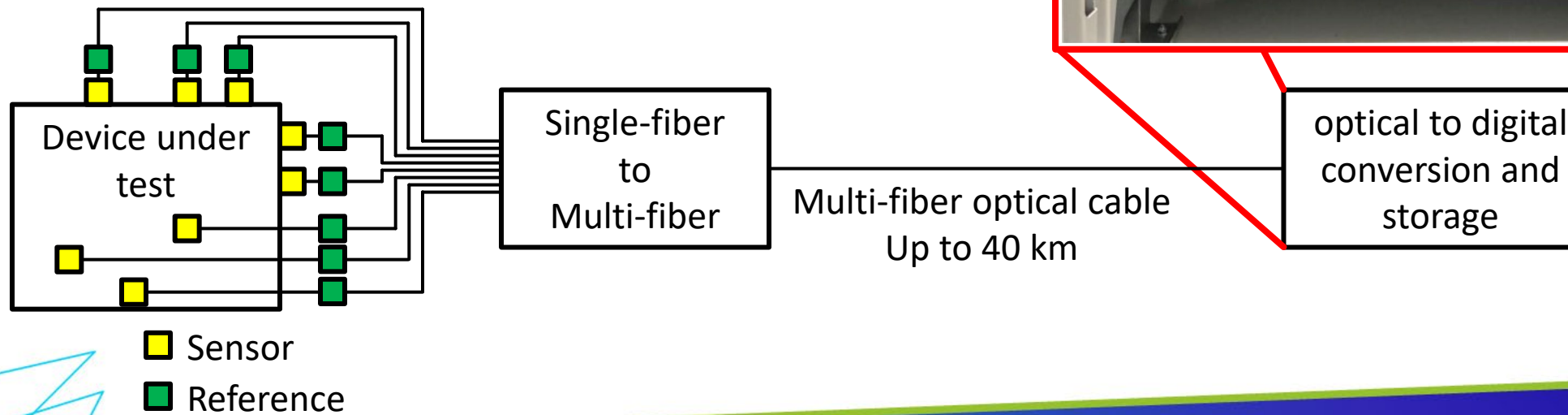
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Acoustic localization – System overview

Optifender manufactured by OPTICS11

- Fully passive fiber optic sensors
- Up to 32 sensors
- EMC hard
- Based on Michelson interferometry



Acoustic localization – System overview

- Fully autonomous: No dependencies
- Optional
- Synchronization with supply voltage: acoustic PRPD
- Synchronization with electric PD trigger: Increased accuracy and sensitivity



Acoustic localization

- Fully autonomous:

No dependencies

Optional

- Synchronization with supply voltage:
- Synchronization with electric PD trigger:

acoustic PRPD

Increased accuracy and sensitivity

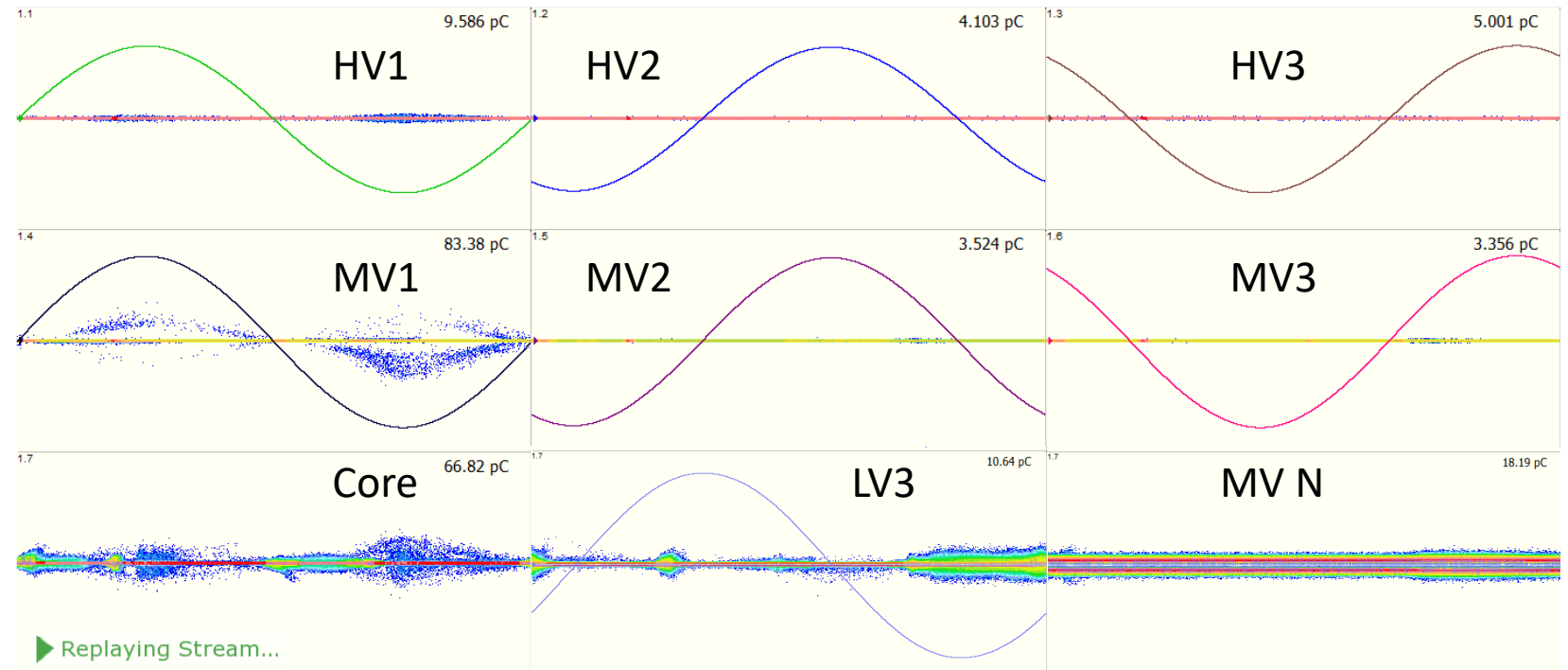
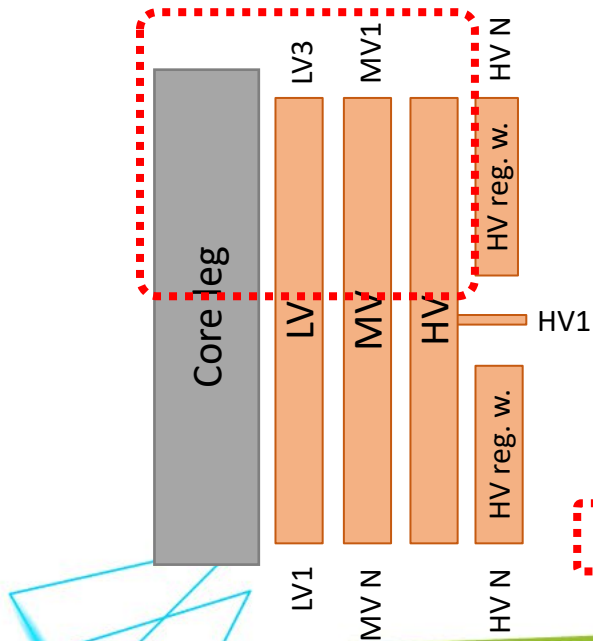


Coarse PD localization

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- Internal PD

Measure on other terminals

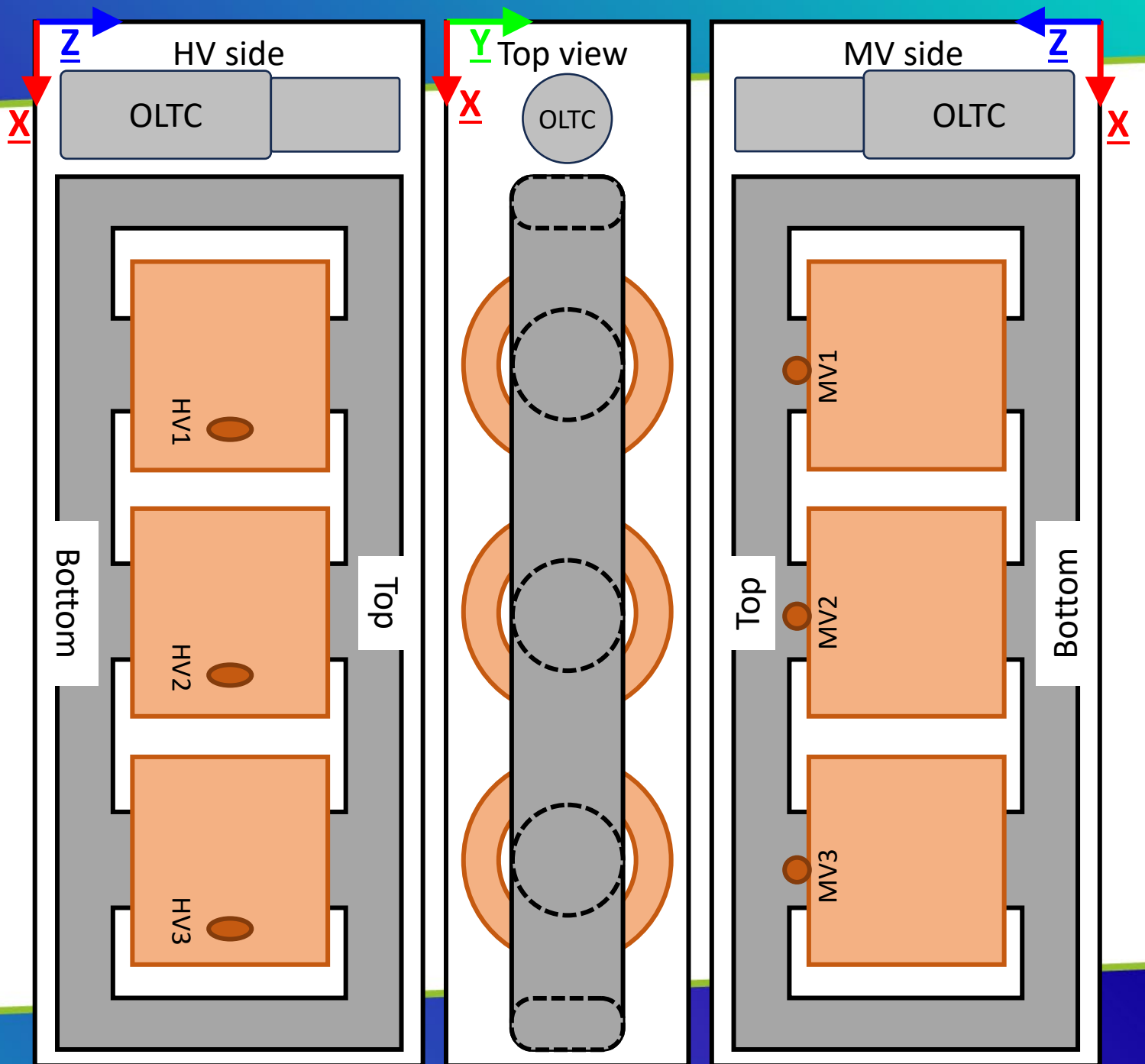


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Acoustic localization

Example

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- PD on MV1

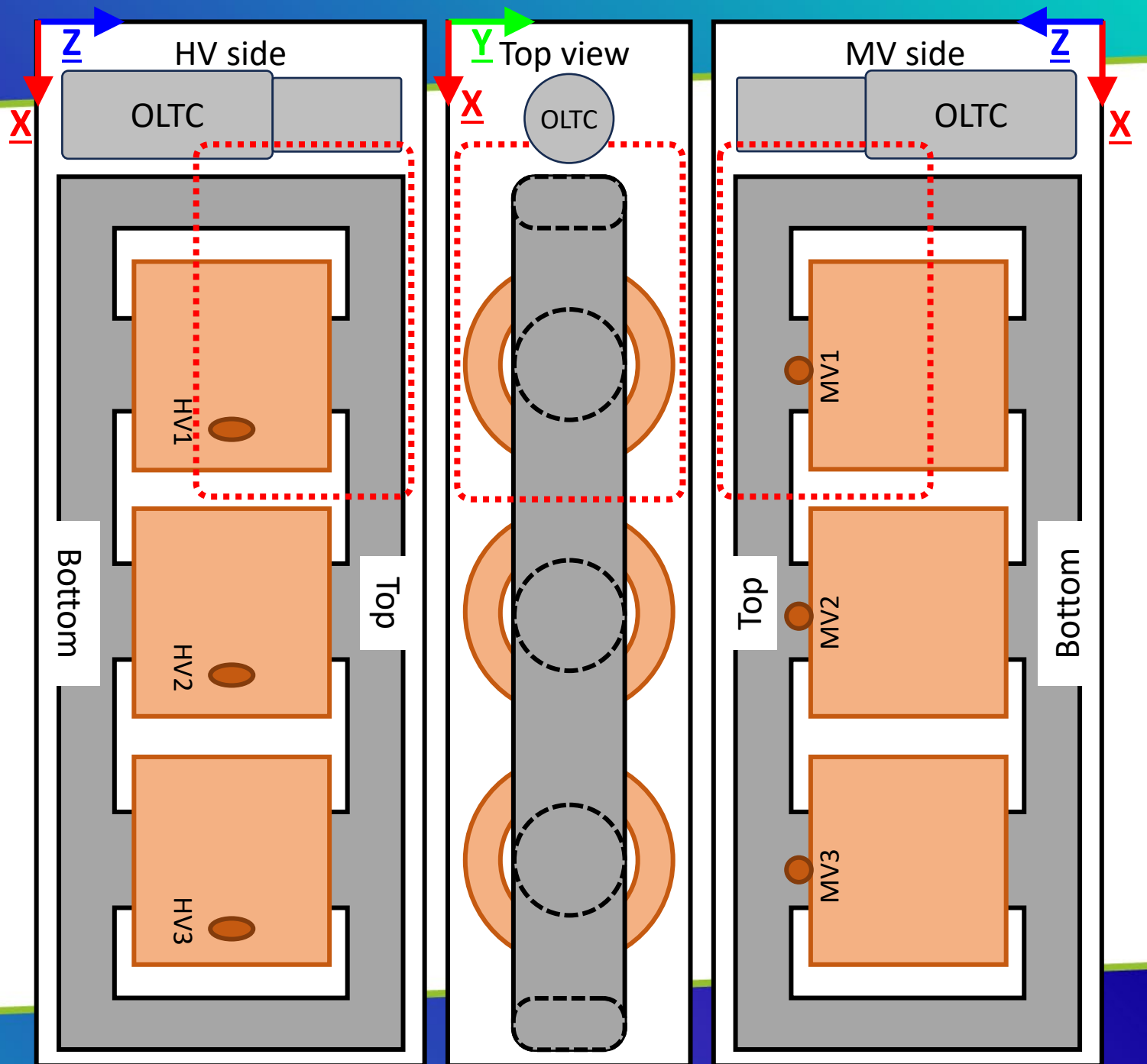


Acoustic localization

Example

- YNyn0d5
- PD on MV1
- Start area: top first phase

Search area based on
coarse PD localization



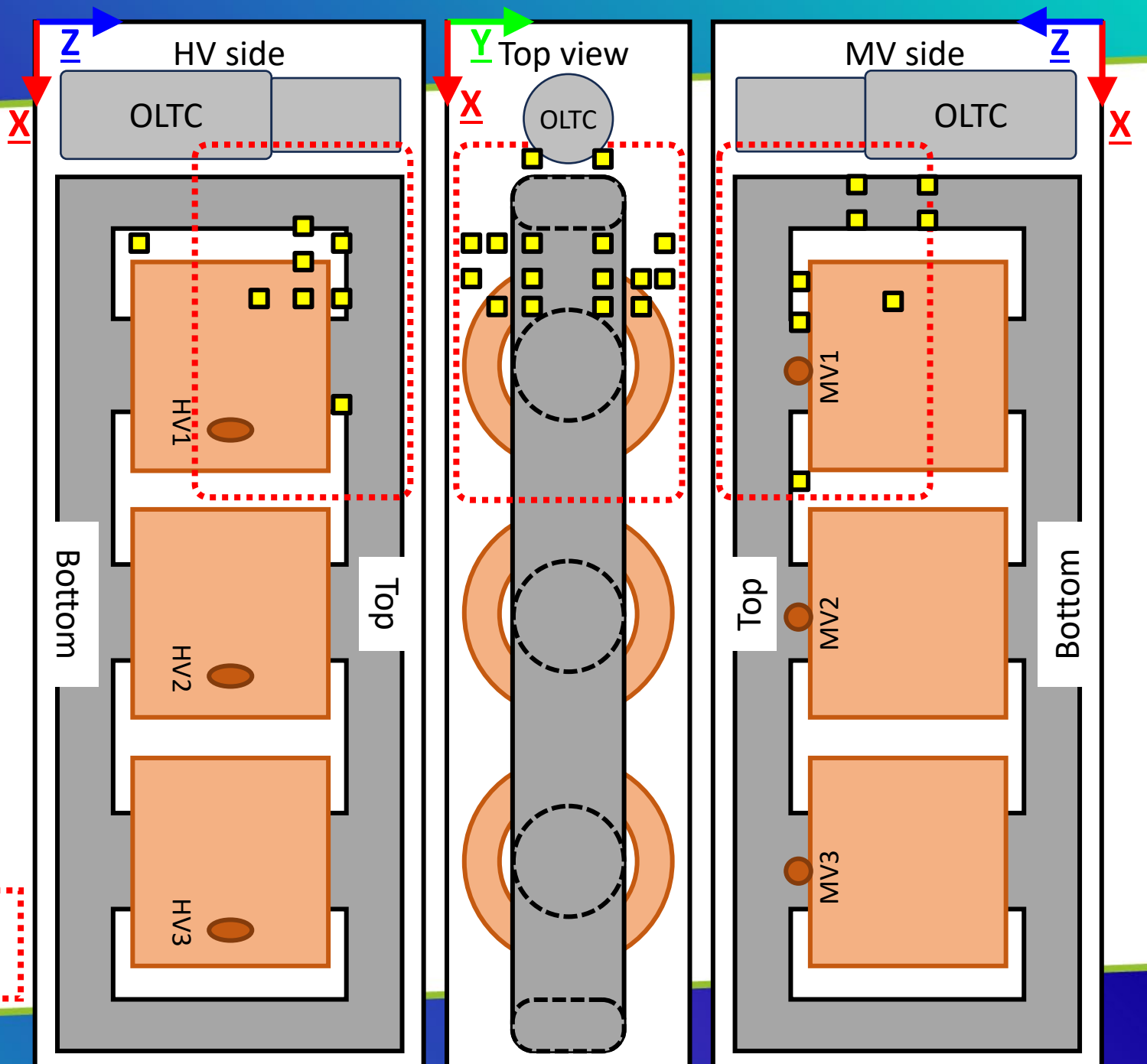
Acoustic localization

Example

- YNyn0d5
- PD on MV1
- Locations determined by:
 - Coverage
 - Sensor field of view
 - Practical, accessibility

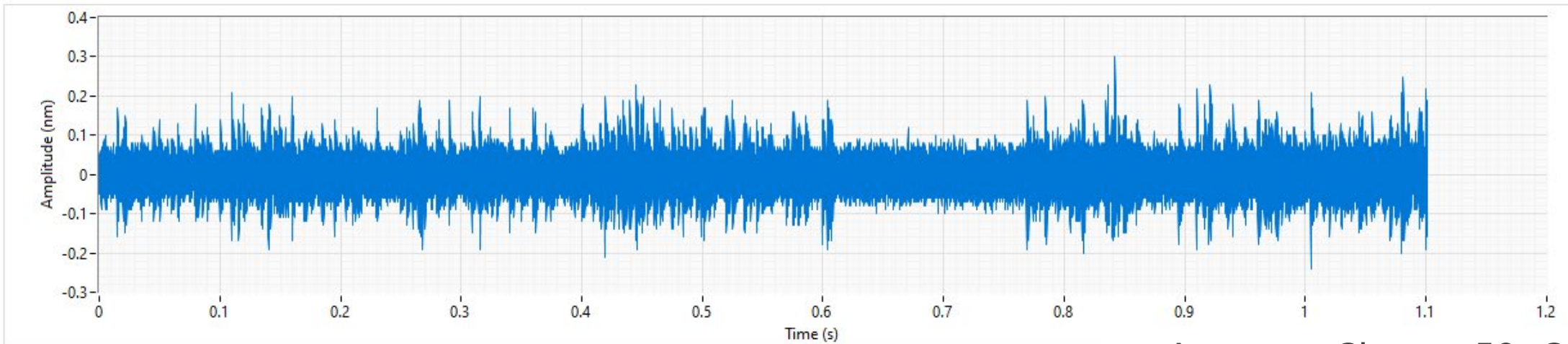
■ Sensor

Search area based on coarse PD localization

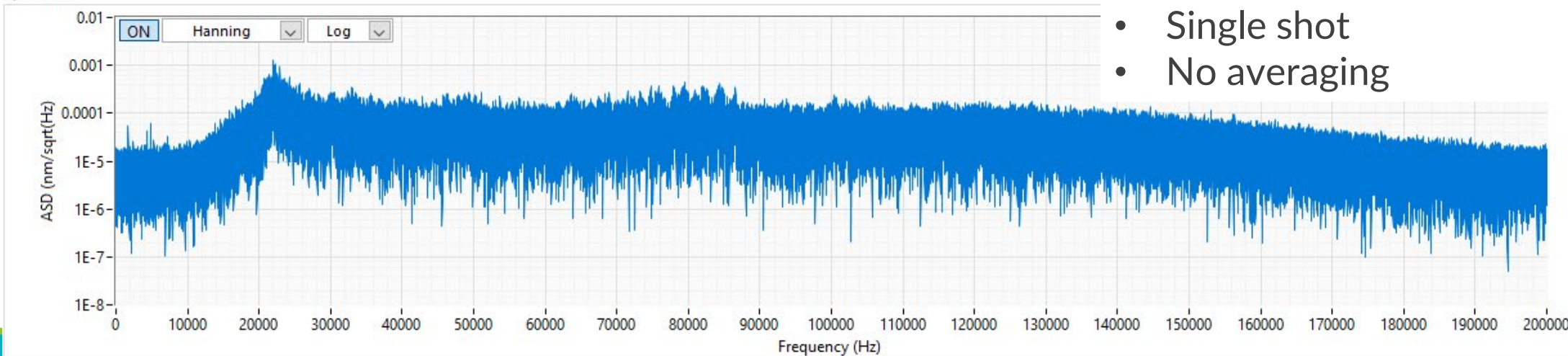


Acoustic localization - Time signals

Time Data



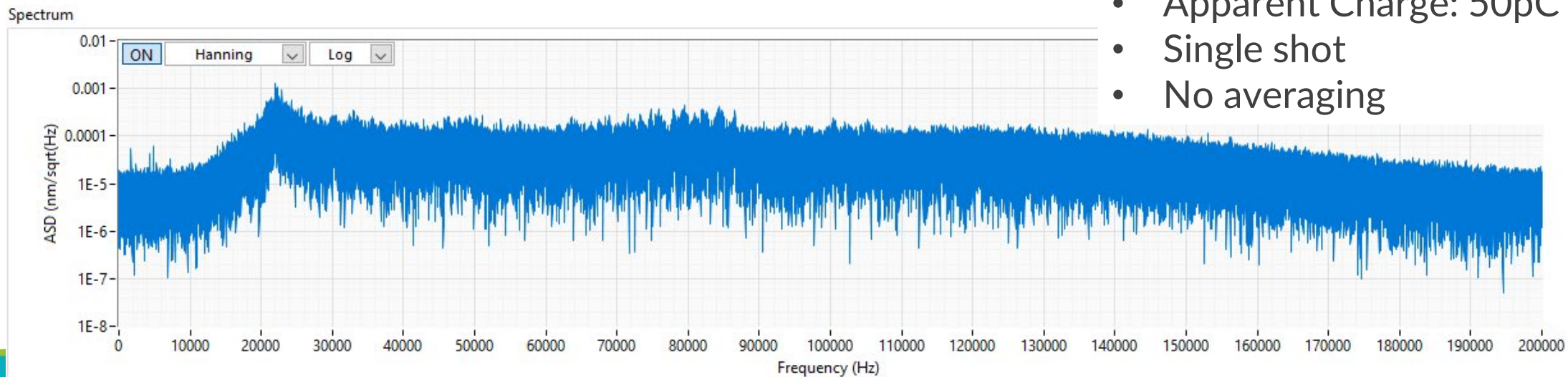
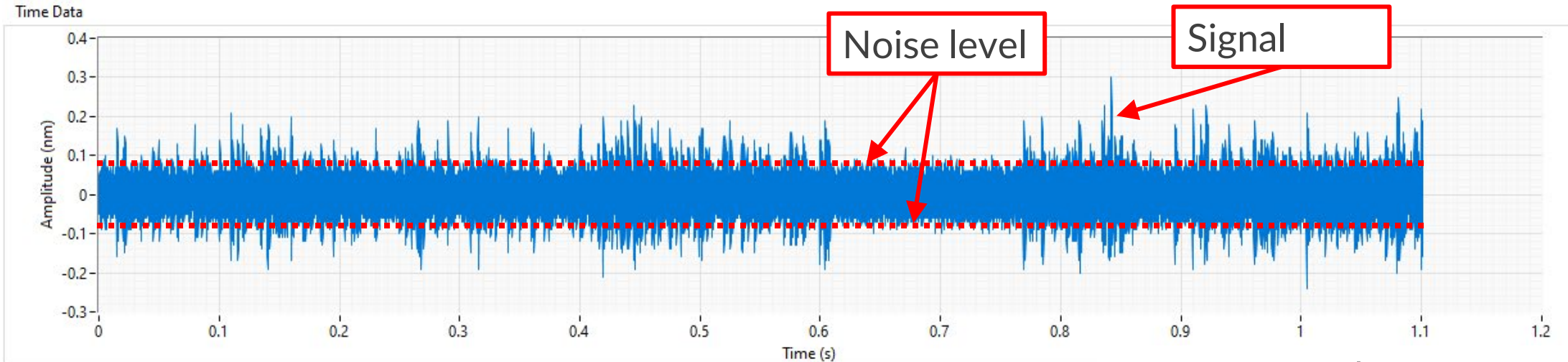
Spectrum



- Apparent Charge: 50pC
- Single shot
- No averaging

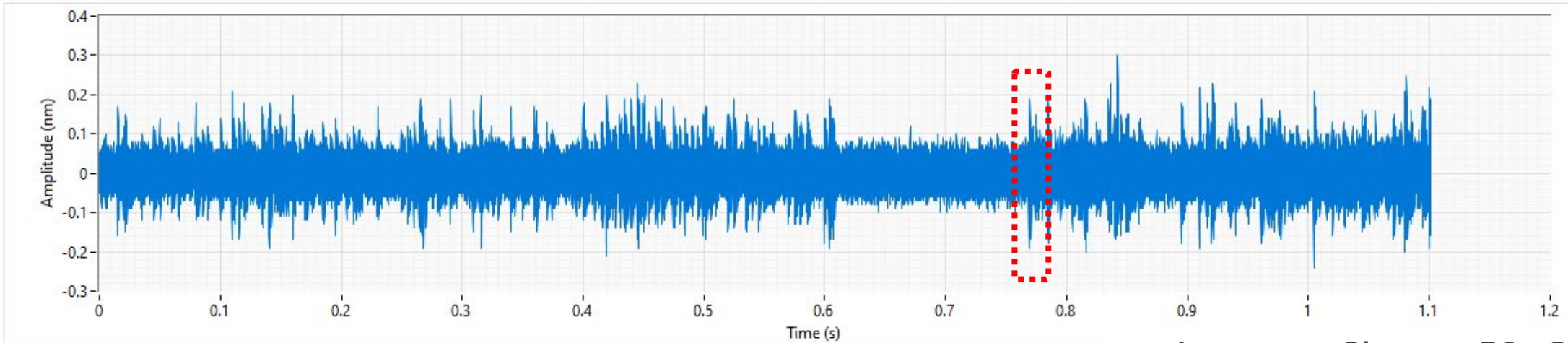


Acoustic localization - Time signals

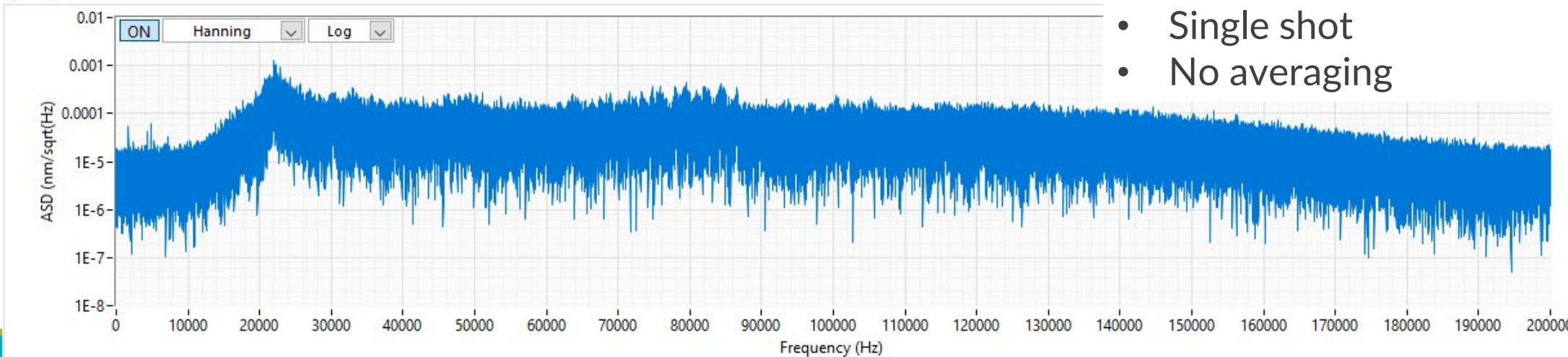


Acoustic localization - Time signals

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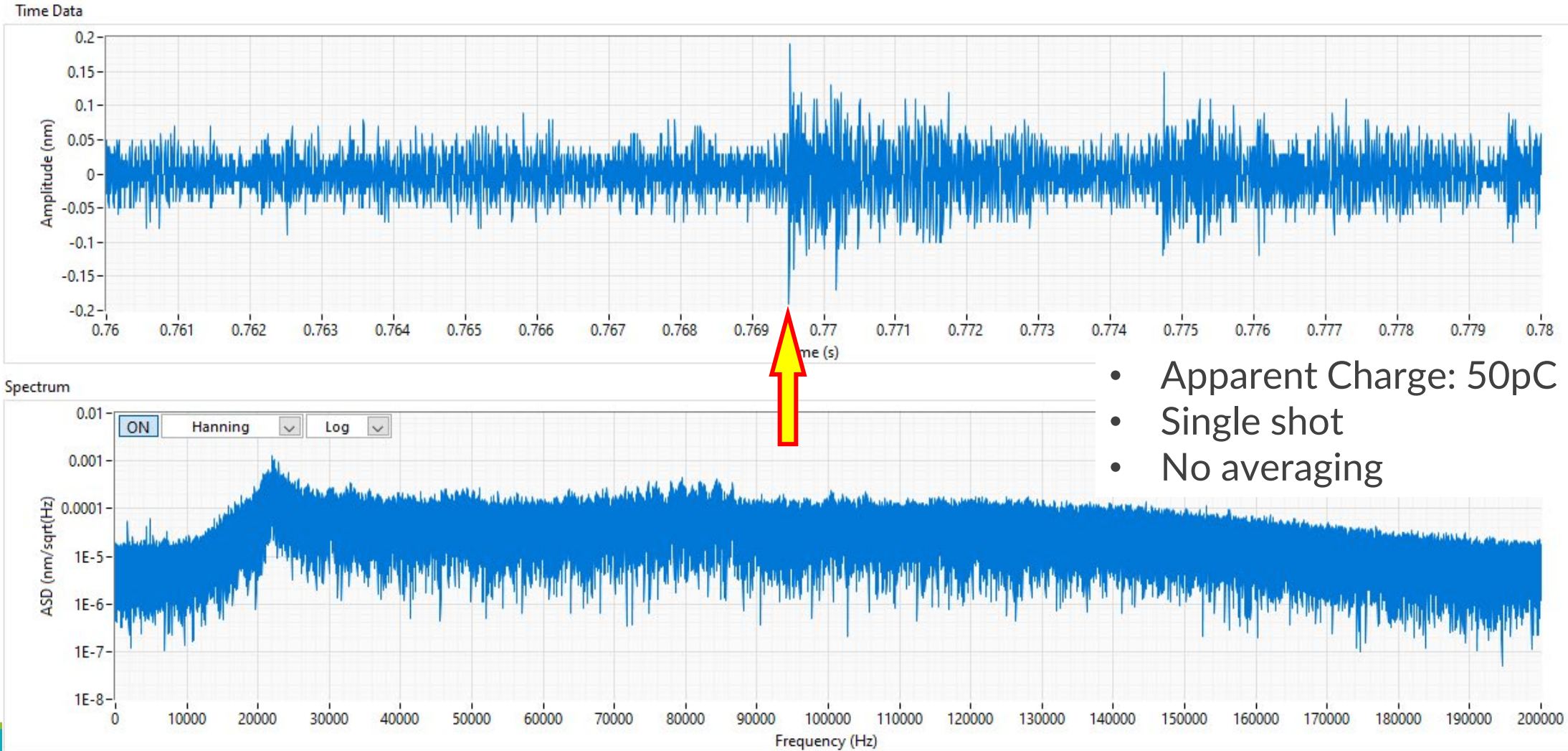
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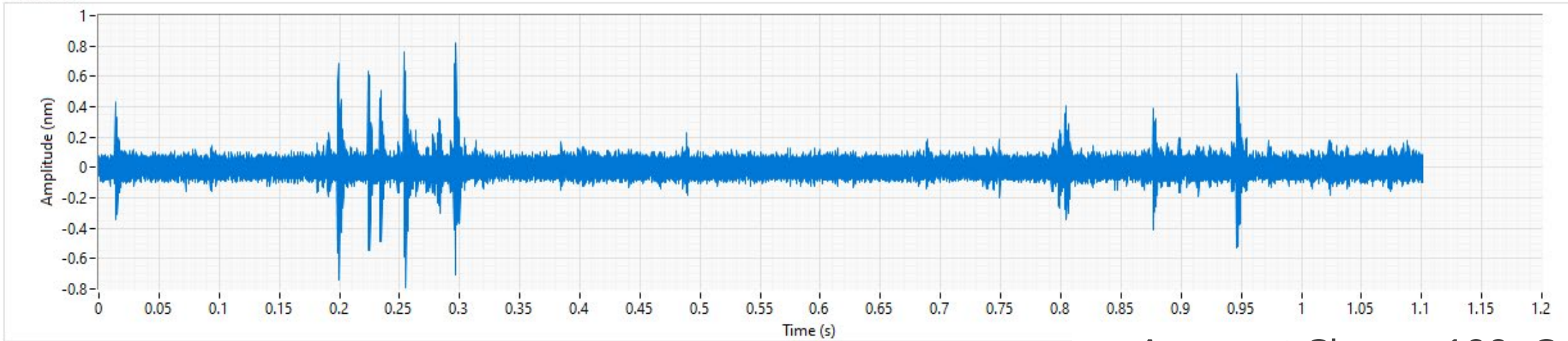


Acoustic localization - Time signals

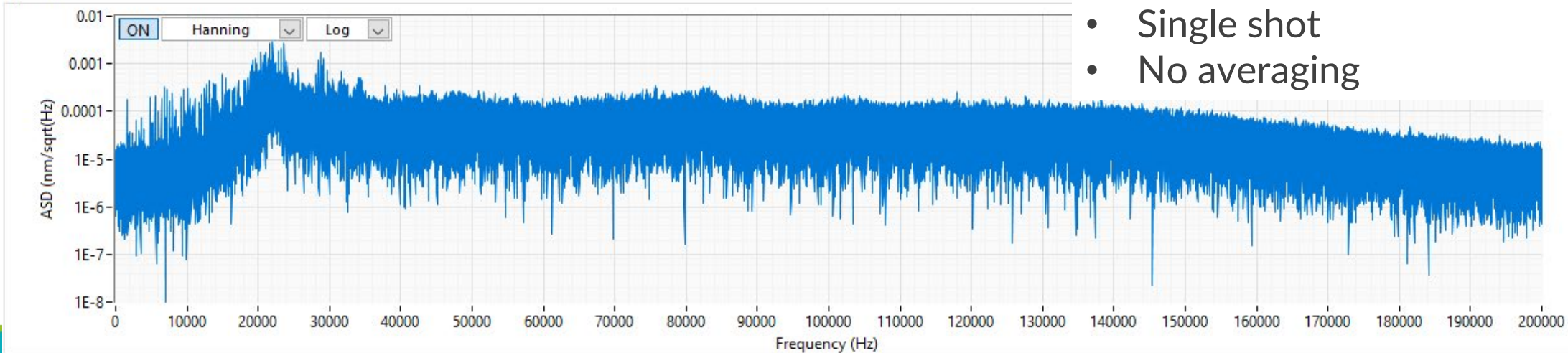


Acoustic localization - Time signals

Time Data



Spectrum

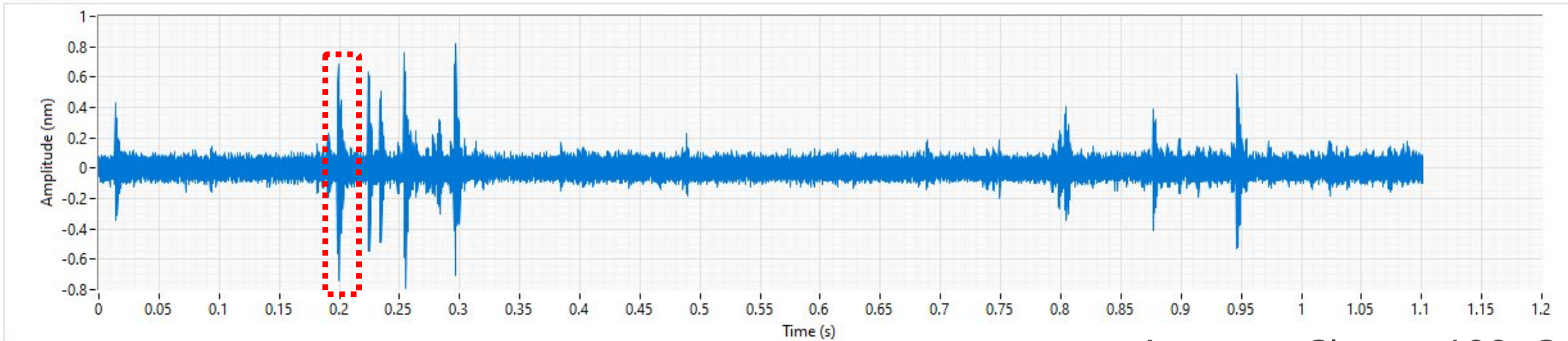


- Apparent Charge: 100pC
- Single shot
- No averaging

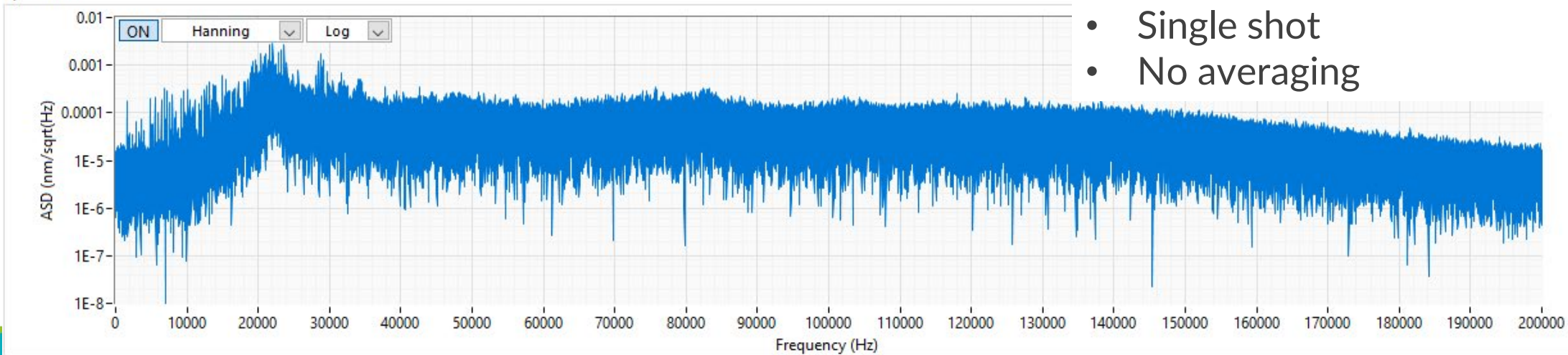


Acoustic localization - Time signals

Time Data



Spectrum

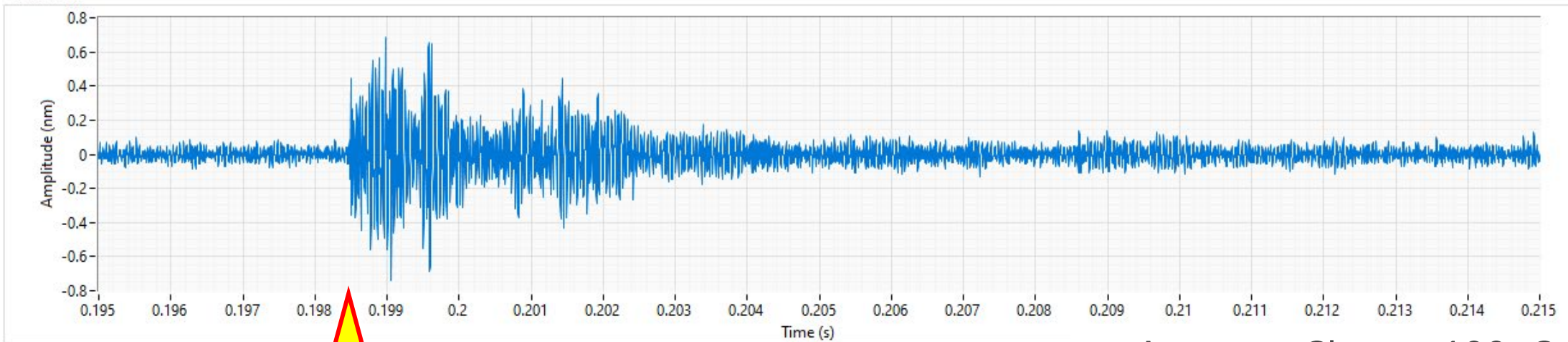


- Apparent Charge: 100pC
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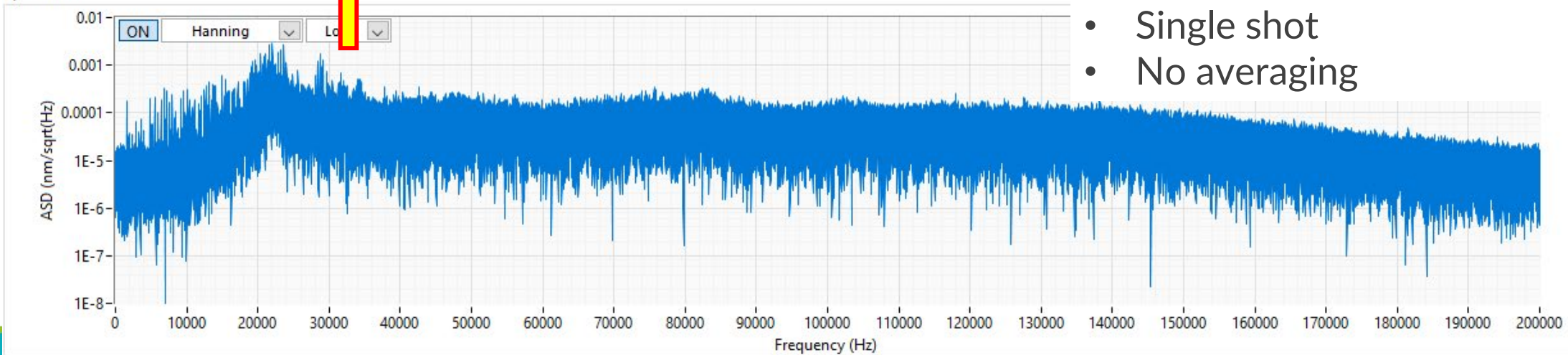


Acoustic localization - Time signals

Time Data



Spectrum

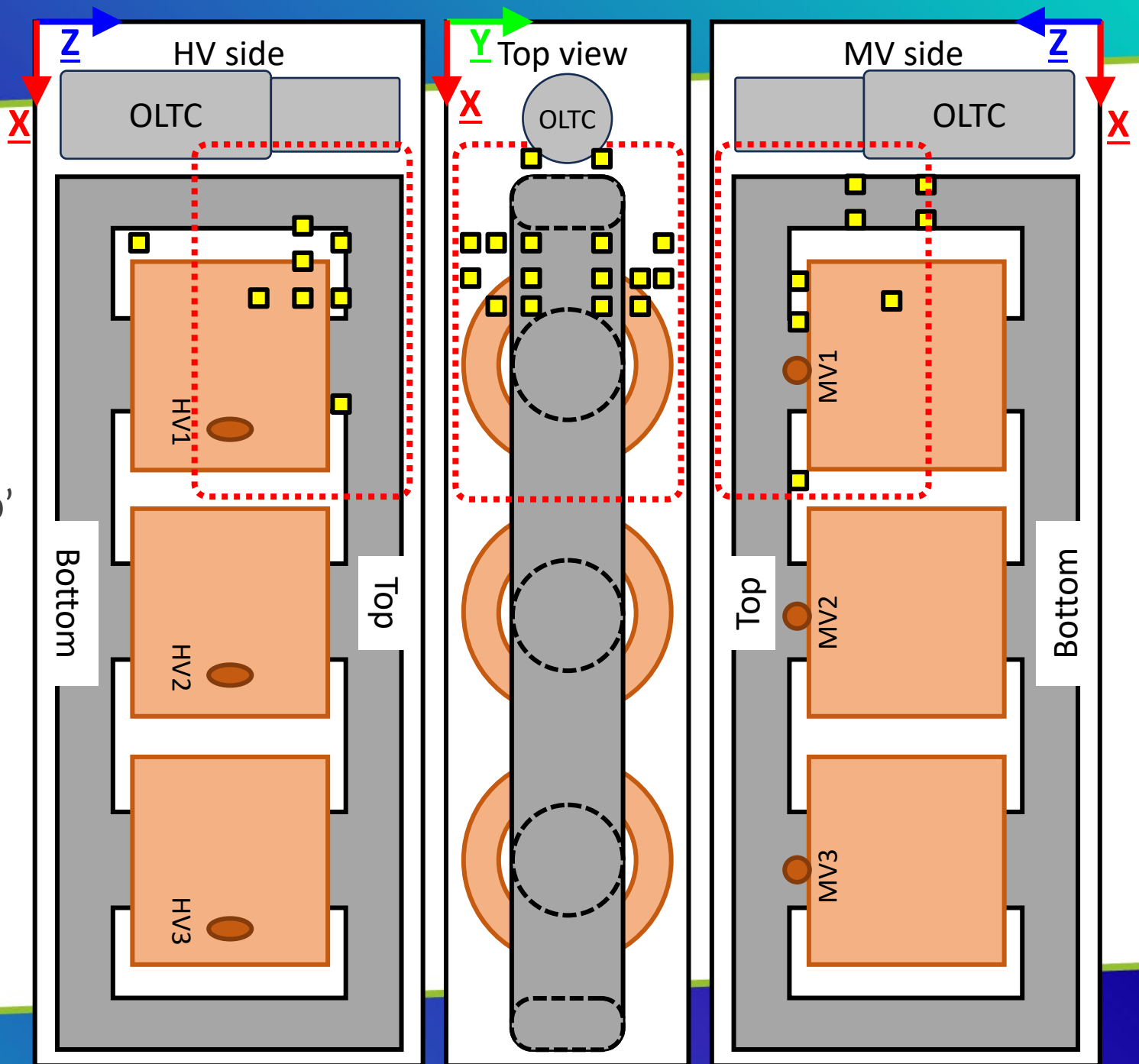


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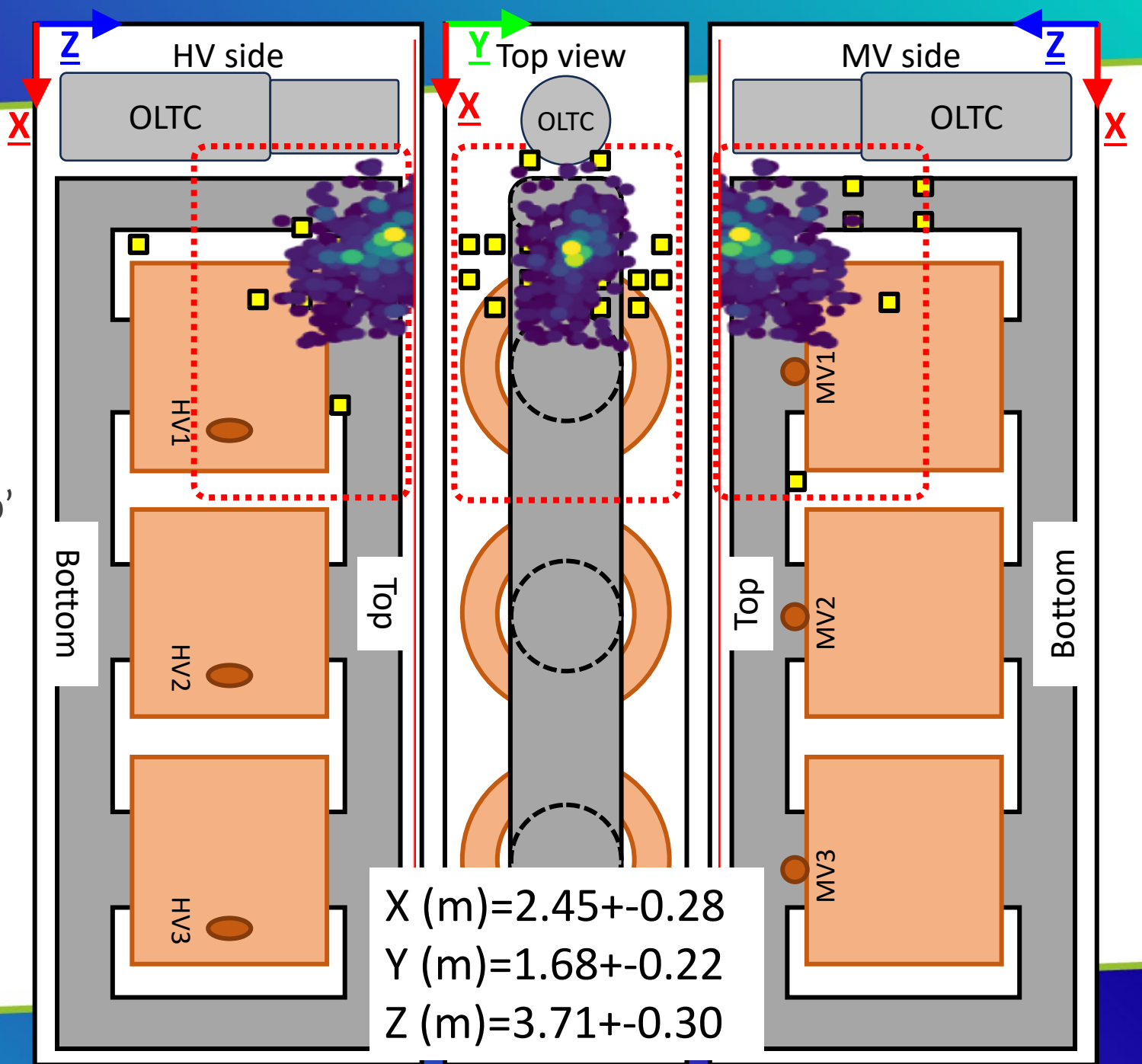
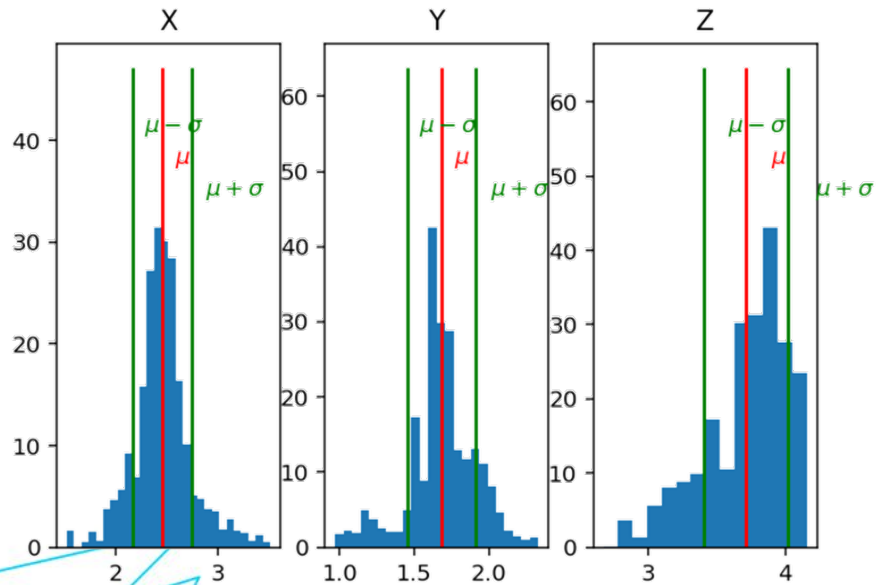
Acoustic localization

- 4 acoustic signals needed
- Sensitive sensors:
 - No averaging needed
 - Allows for signal statistics
- Location indicated with 'heat map'



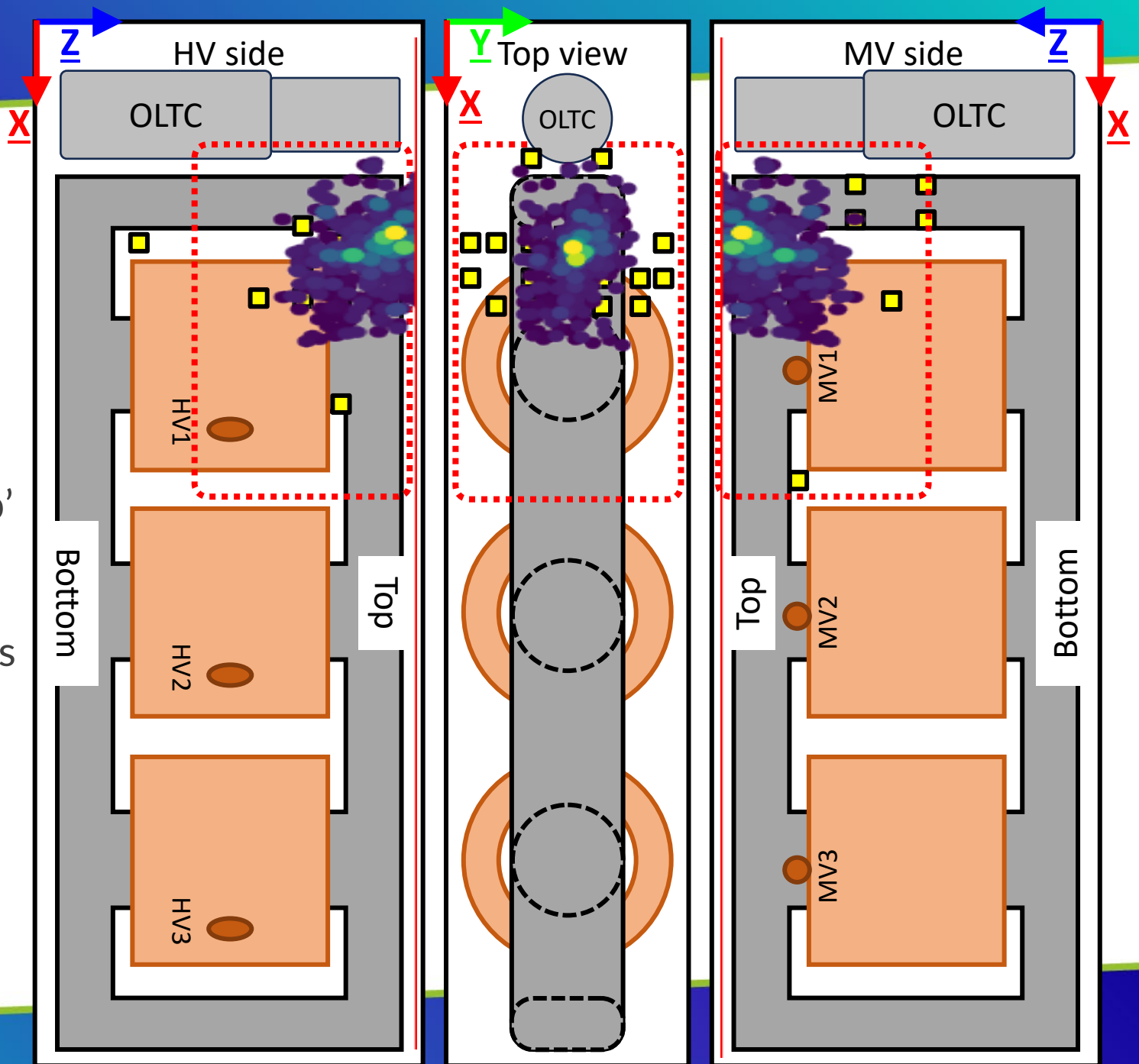
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Acoustic localization

- 4 acoustic signals needed
- Sensitive sensors:
 - No averaging needed
 - Allows for signal statistics
- Location indicated with 'heat map'
- Results require interpretation
 - Calculate with $V_{oil} = 1390$ m/s
 - Some signals come through the core; $V_{steel} \gg 1390$ m/s
 - Location 'too high'



Conclusions

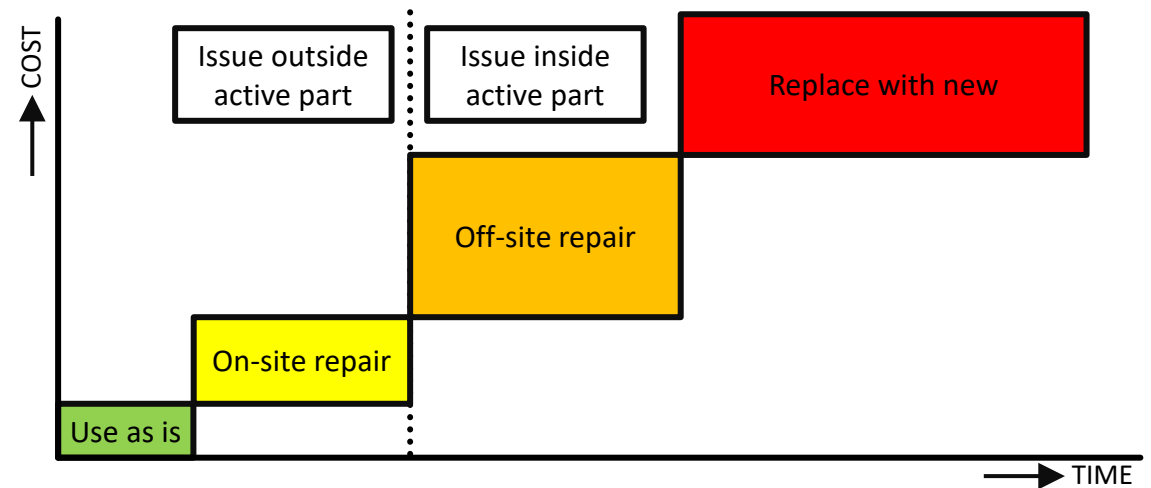
Acoustic localization with Optifender:

1. Fast → Reduce Test time and cost,
2. Reliable → More predictable planning,
3. Accurate → Faster and better inspection and repair
4. Autonomous → Technique accessible for test team, less need for expert



Outlook

1. Use acoustic emission detection also on other FAT tests
 1. Lightning Impulse,
 2. Applied Voltage test,
 3. ...
2. On site monitoring of partial discharge in substation HV assets
 1. DGA monitoring,
 2. Acoustic localization with Optifender,
 - Very limited down time (~1 day)
 - Better insight in asset issue,
 - Earlier in time,
 - Better prepared to tackle issue,
 3. Transformers, bushings, reactors, ...
 4. GIS installation
 5. Cable termination



Questions?



Thank you!

