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MIDTERM EVENT PARIS

WP7: Crossing monitoring system

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05/02/2026

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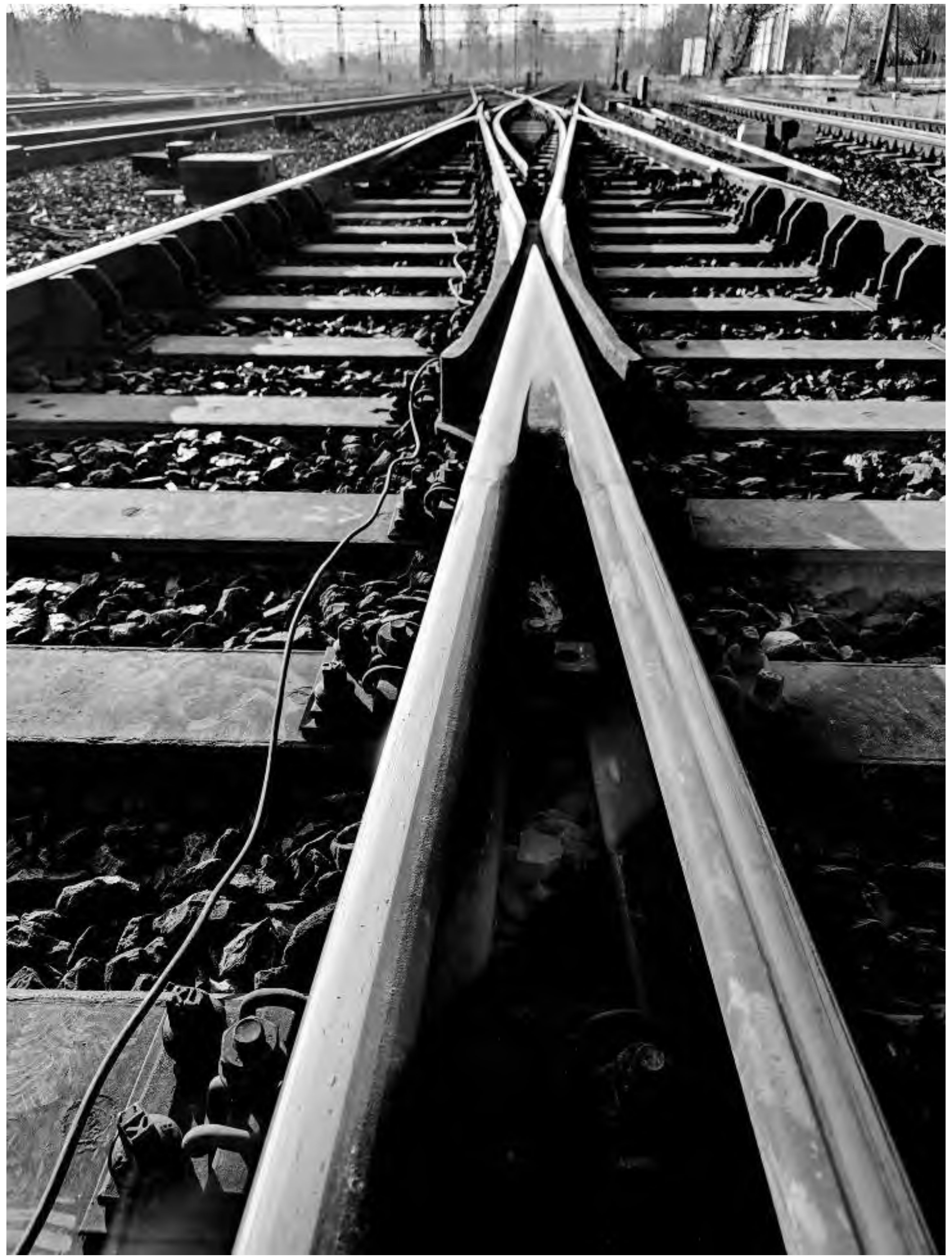


Requirements

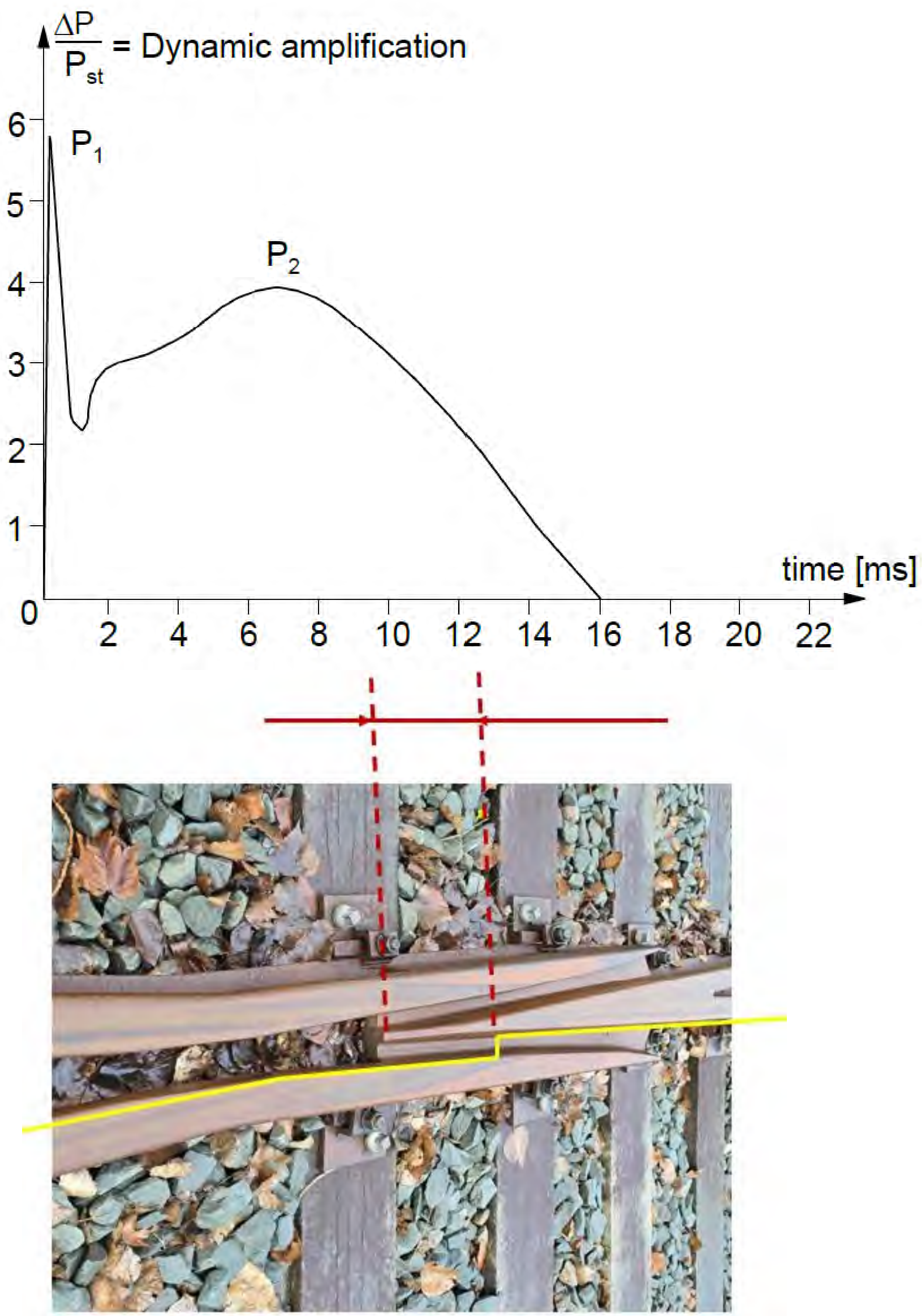
While promising, the sources conclude that **most existing monitoring technologies are not yet fully appropriate** for the specific goal of predicting RCF (Rolling Contact Fatigue). Current systems struggle to precisely estimate the *impact-load accumulation history* at specific locations on the rail surface.

Goal:
determine both the **wheel impact force** and
its **exact location** throughout the load-transfer area.

Monitoring

- Switch from reactive to preemptive maintenance
- Extend the service life of infrastructure
- Instead of detection rolling contact fatigue and wear, predict the process in advance
- Continuous Monitoring is a specific subset of Crossing Monitoring
- **Continuous monitoring** specifically aims to
  - frequent,
  - real-time data streams
  - to enable preventative maintenance rather than corrective repairs
  - fills the gap between inspections.
  - trigger "on-demand" inspections or interventions when specific thresholds are breached

Measurement goal



- Measurement of the time function of the first impact
- Measurement of the exact location of the first impact load
- Magnitude of the wheel impact force (P1)
- Accumulated Impact-Load History mapped to the specific location
- Exact longitudinal position: distribution profile of load intensity
- Zones of accumulated highest impacts
- The detection of an "unfavorable accumulation of impacts" (a concentration of high loads in a specific zone)

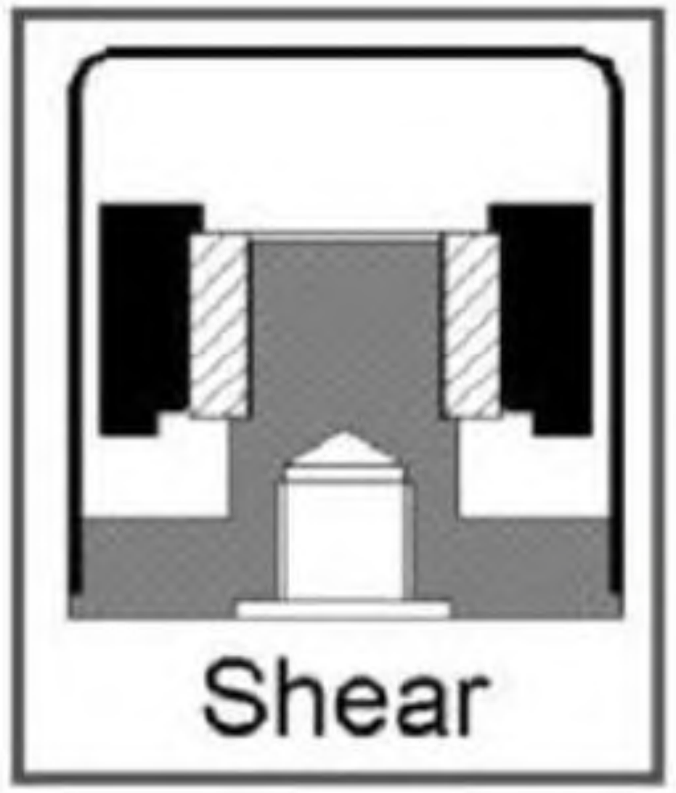
Requirements

Vertical axeleration	0-600g
Accuracy of acceleration	1%
Frequency range	0.5 - 25 kHz
Location of impact	0-100 cm
Spatial resolution	5 mm
Vehicle speed	5 km/h-160 km/h
Rail type	UIC 48, 49, 54, 60
Crossing type	Managese, Constructed
Power supply	230V 50 Hz
Temperature range	-25°C ...60°C
Remote management	Data server in cloud

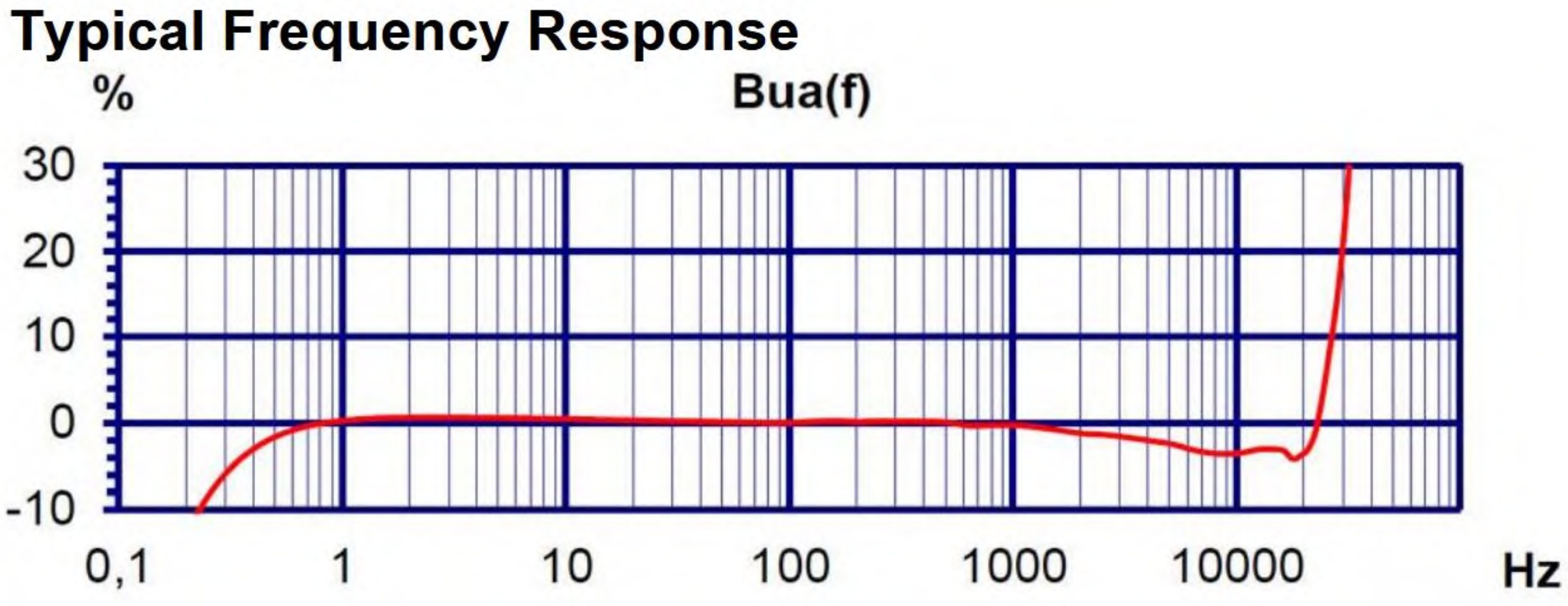
Goals of the demonstrator system

- Validation of the requirements
- Determine the frequency bandwidth
- Testing sensor types
- Testing mechanical coupling methods
- Evaluation data processing methods
- Industrial grade system
  - Continuous data recording
  - Real-time operation
  - Permanent installation

Piezo Acceleration sensor

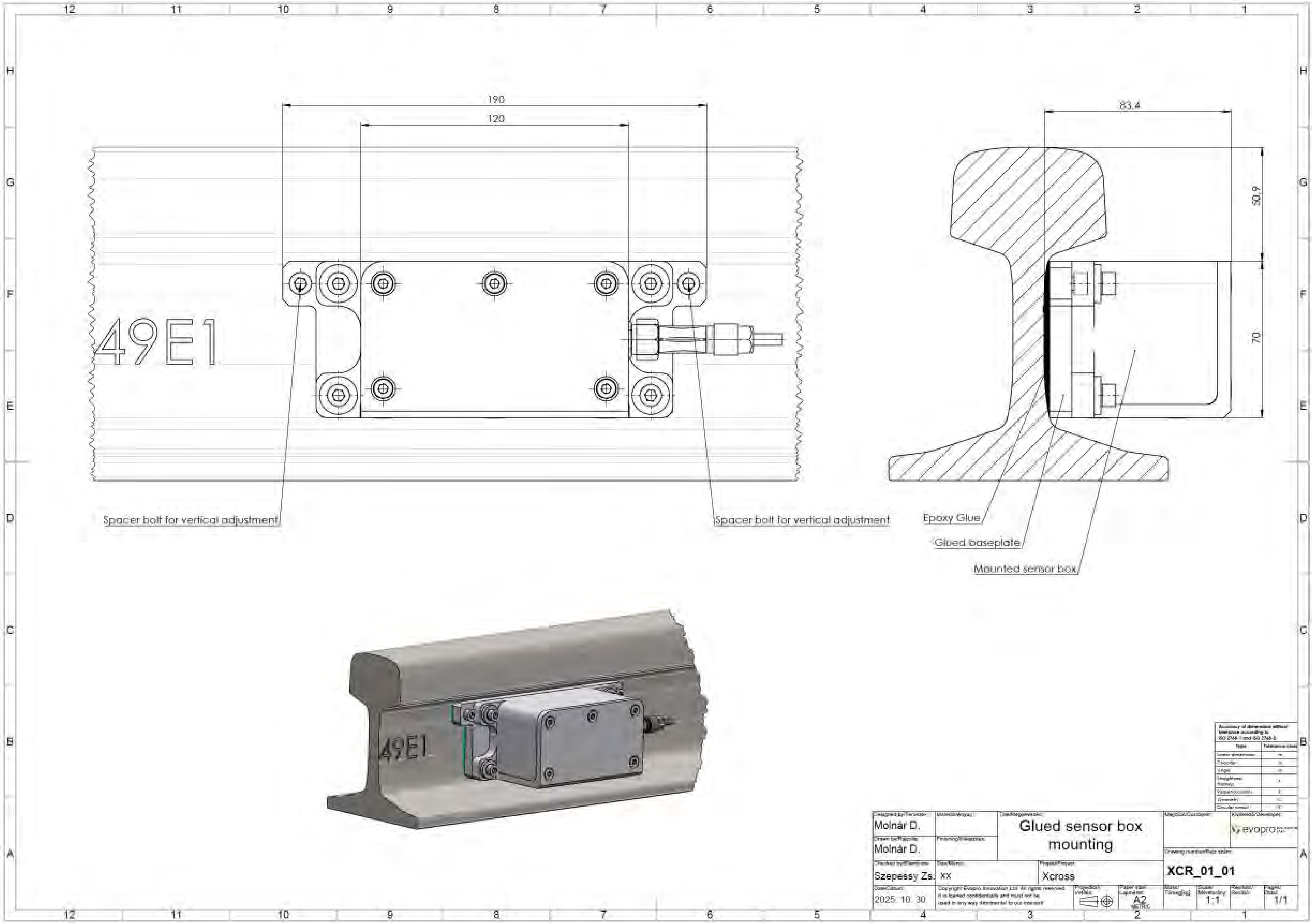


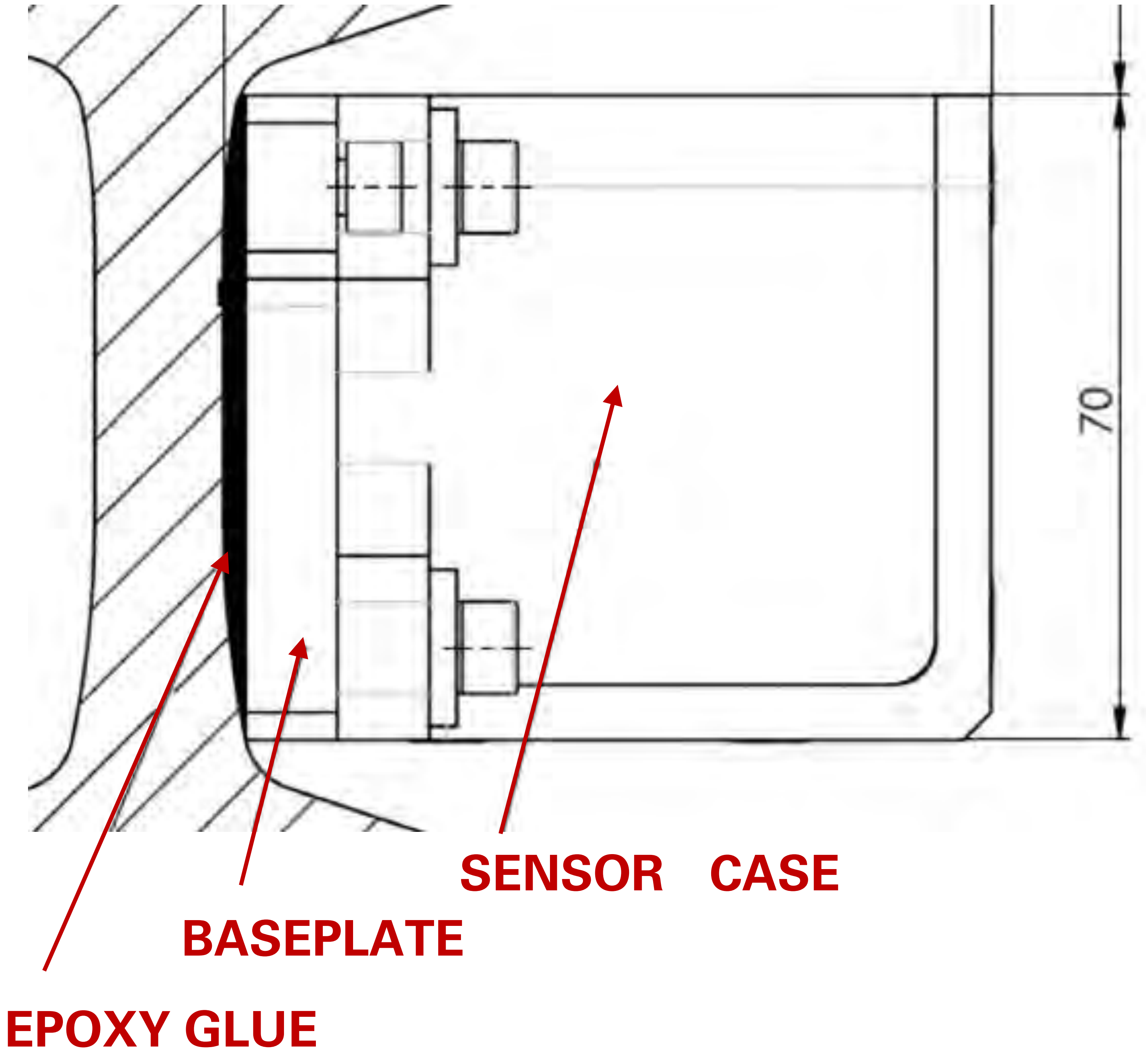
±600g
Shear design
0.12-33kHz



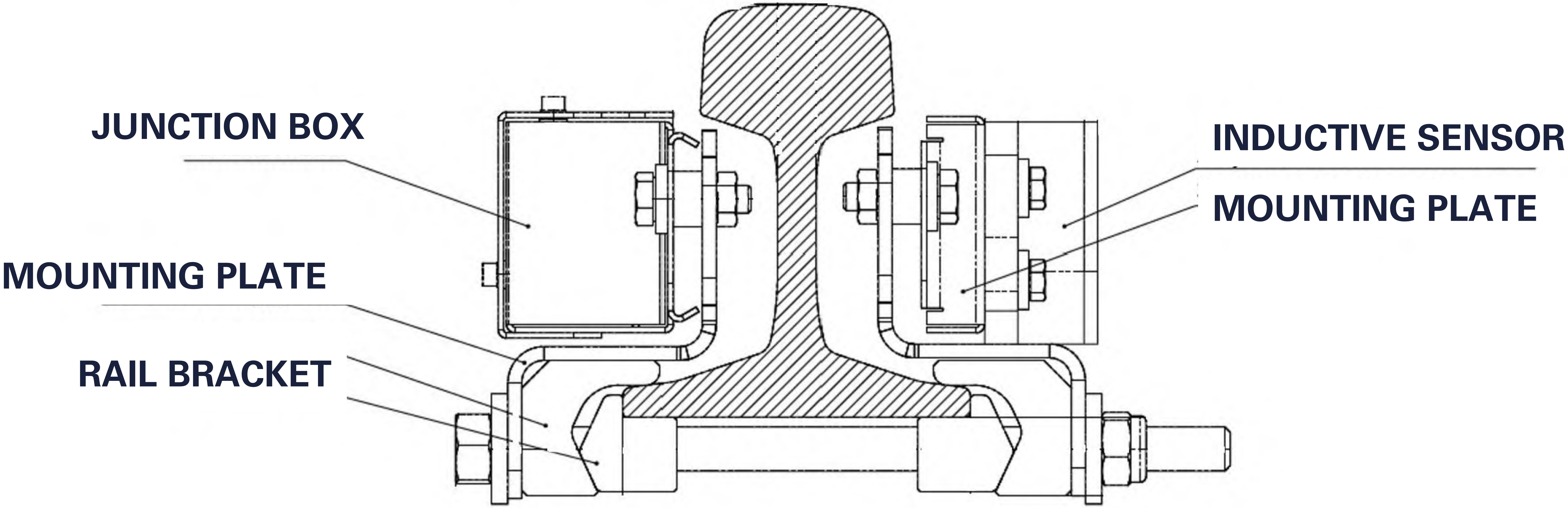
Output	IEPE
Mass	20 g
Sensivity	10 mV/g
Measuring range	6000 m/s^2
Lower frequency limit (3 dB)	0,12 Hz
Upper frequency limit (3 dB)	33 kHz
Connection	UNF 10-32, radial
Mounting	M5 female thread
Working temperature range	-40 .. 130 °C

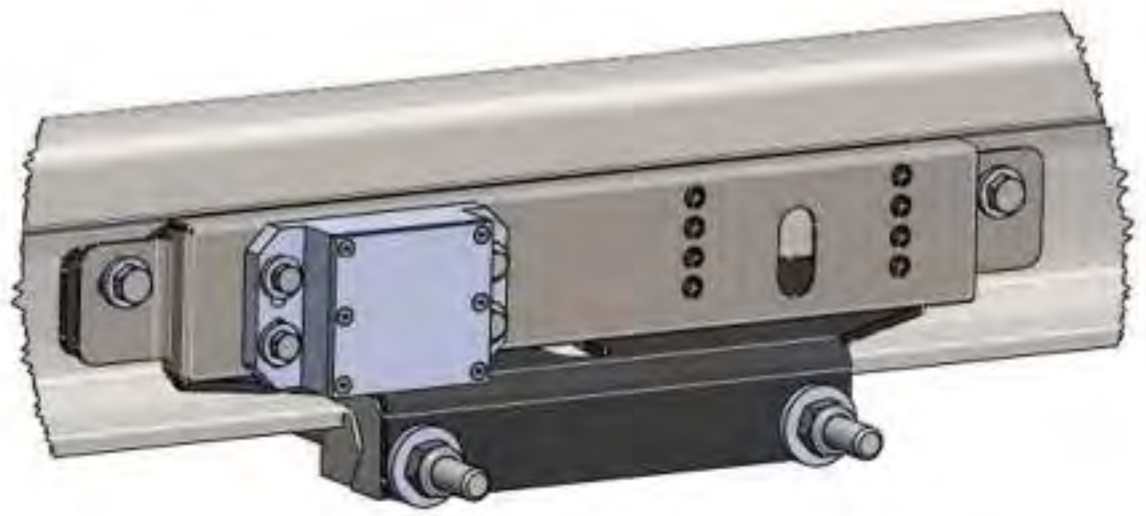
Sensor case and mounting



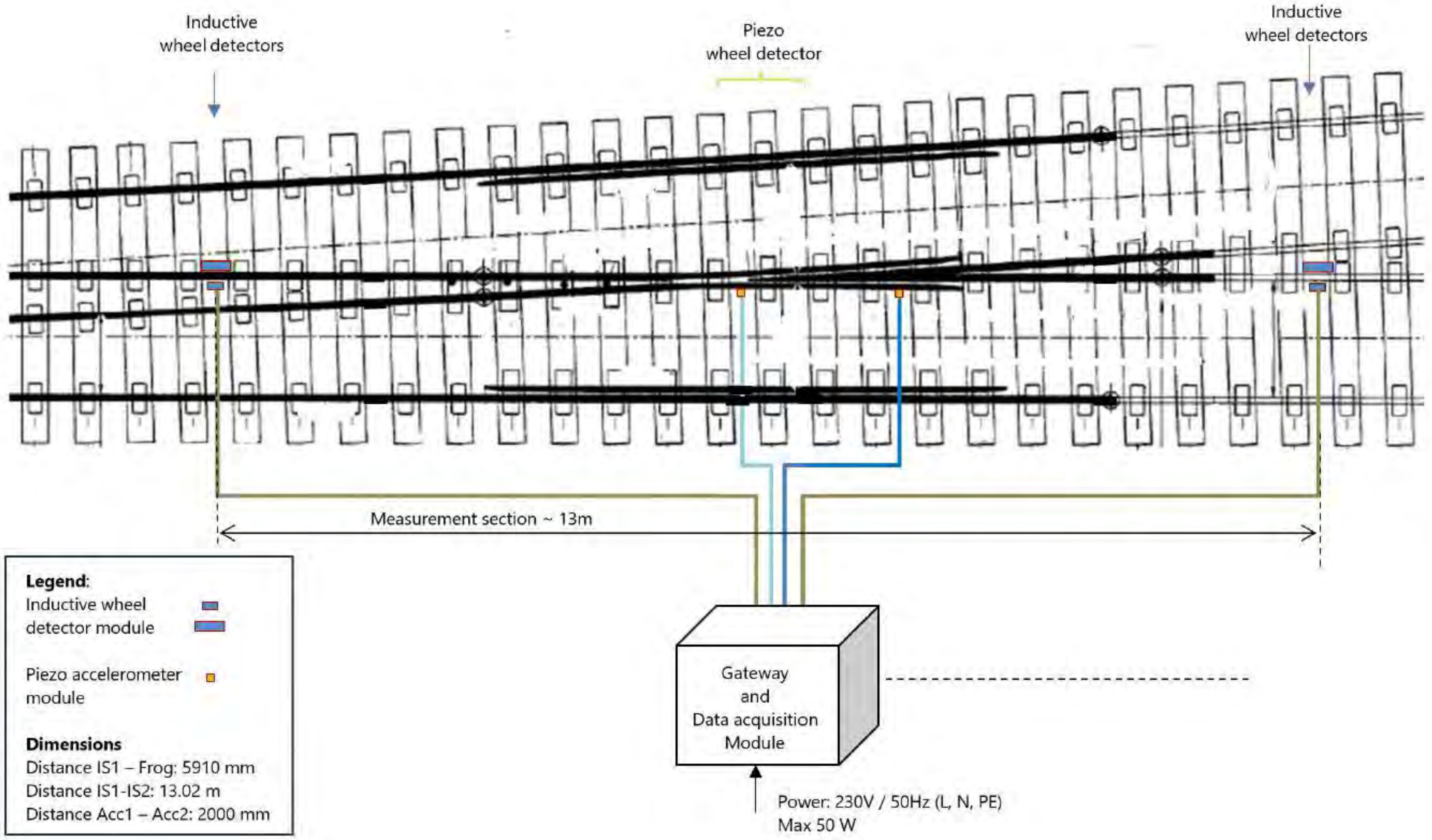


Inductive sensor for wheel detection





Demonstration system

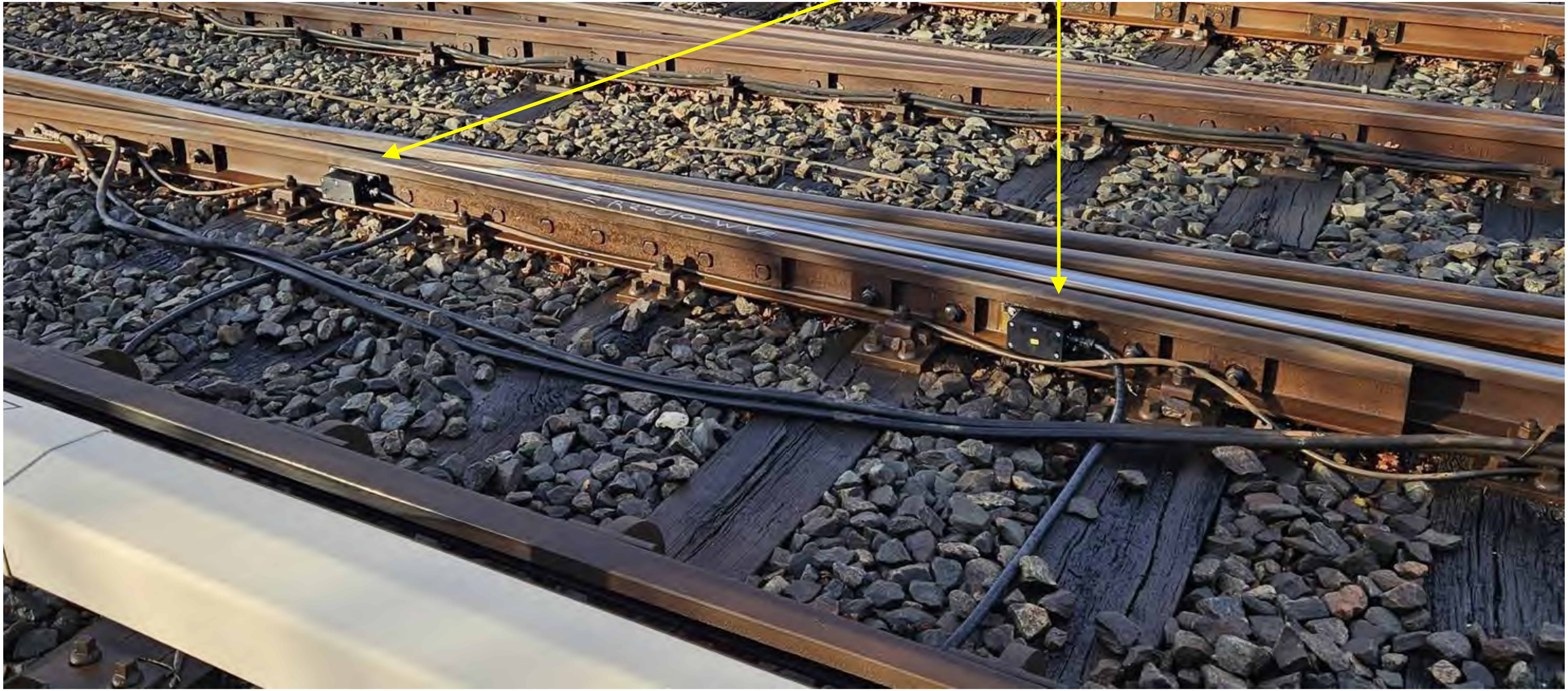


Demonstration system location
Rotterdam Avelingen (51°51'25.9"N 4°21'51.6"E)

Crossing in demonstration site

Piezos sensor modules

Accelerometers

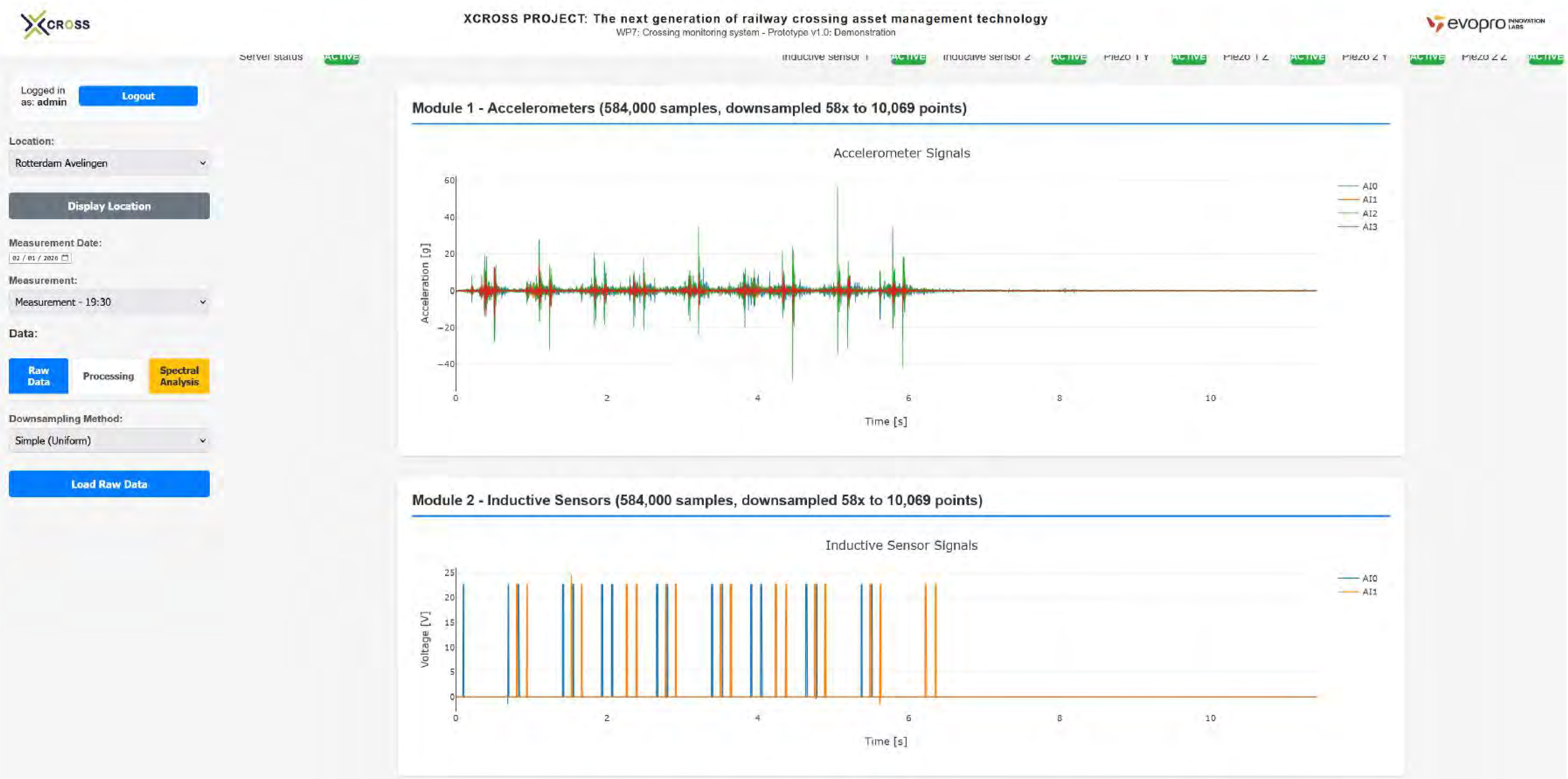


Sensor module on the crossing

Inductive sensor

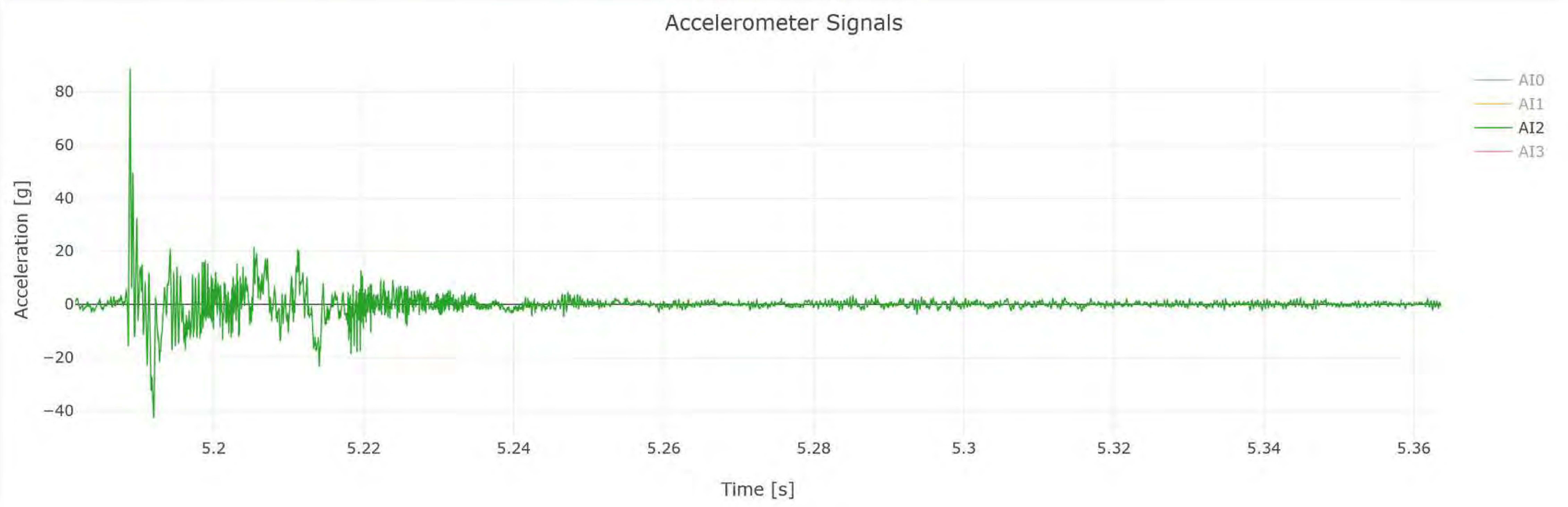
Gateway module

User Interface
https://xcross.northeurope.cloudapp.azure.com/



Zooming in acceleration signal (Y)

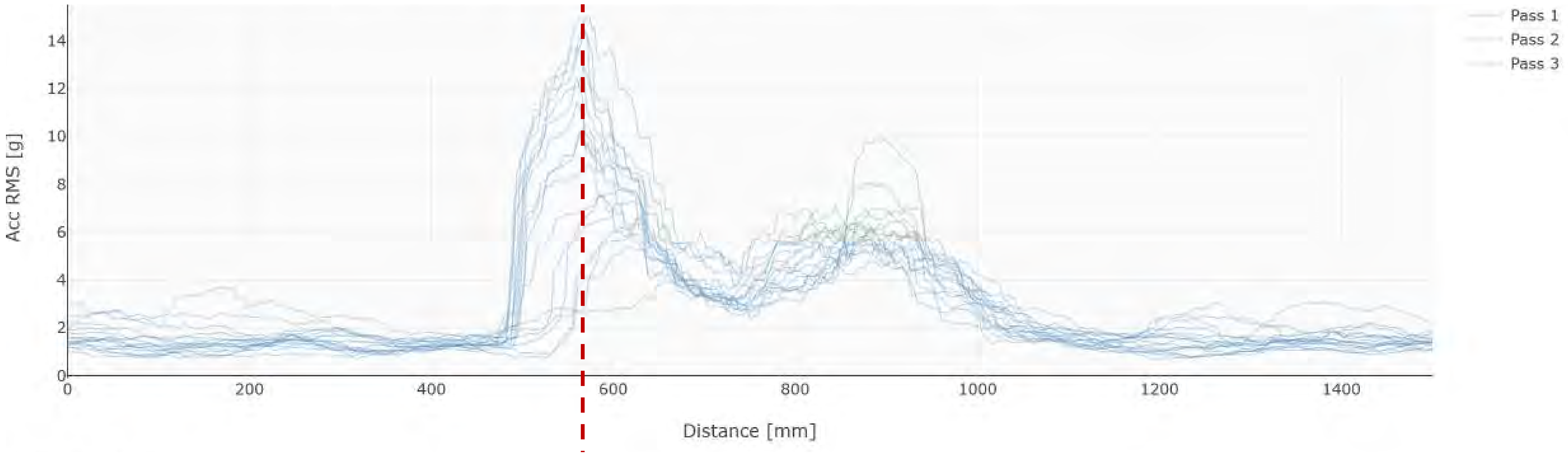
Module 1 - Accelerometers (FULL RESOLUTION: 19,285 samples)



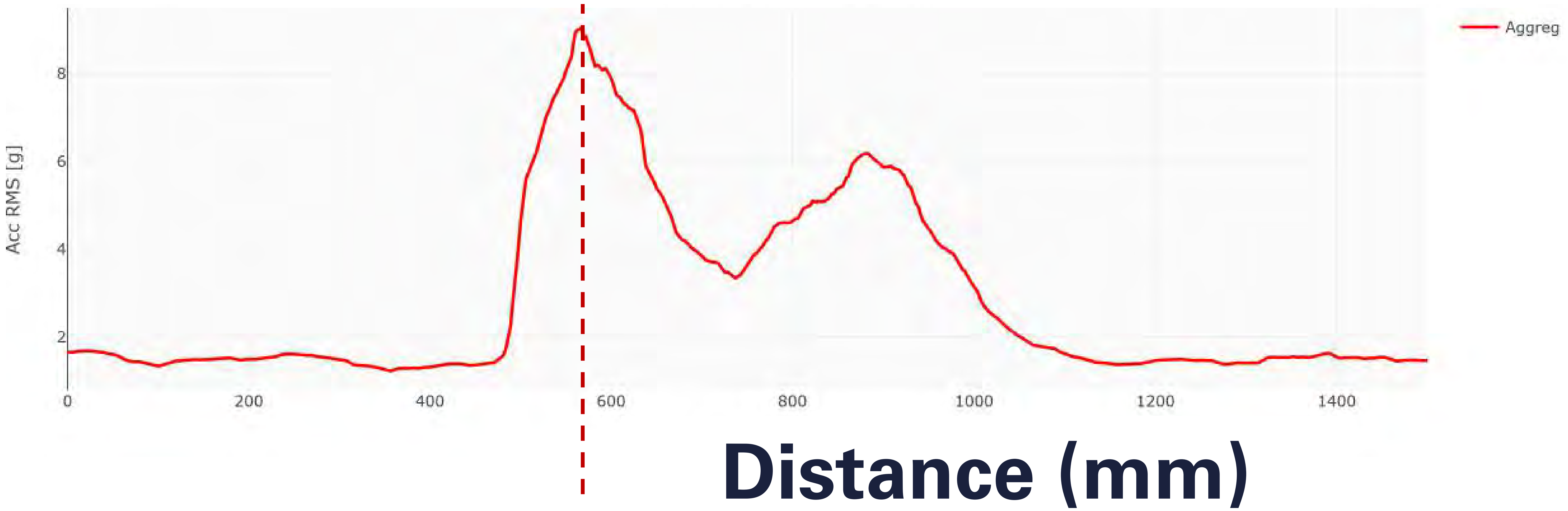
Acceleration RMS

$$\mathrm{RMS}[n] = \sqrt{\frac{1}{M}\sum_{m=n}^{n+M-1} a[m]^2}$$

RMS calculation for each wheel



AGGREGATED SIGNAL



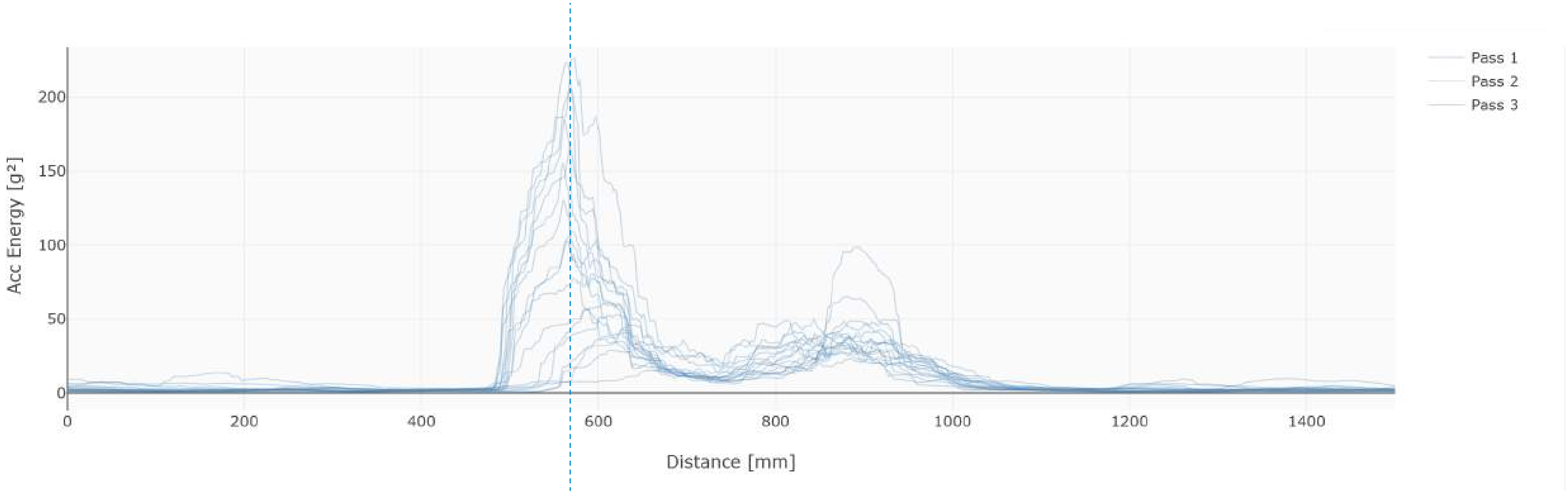
Distance (mm)

P1 impact location

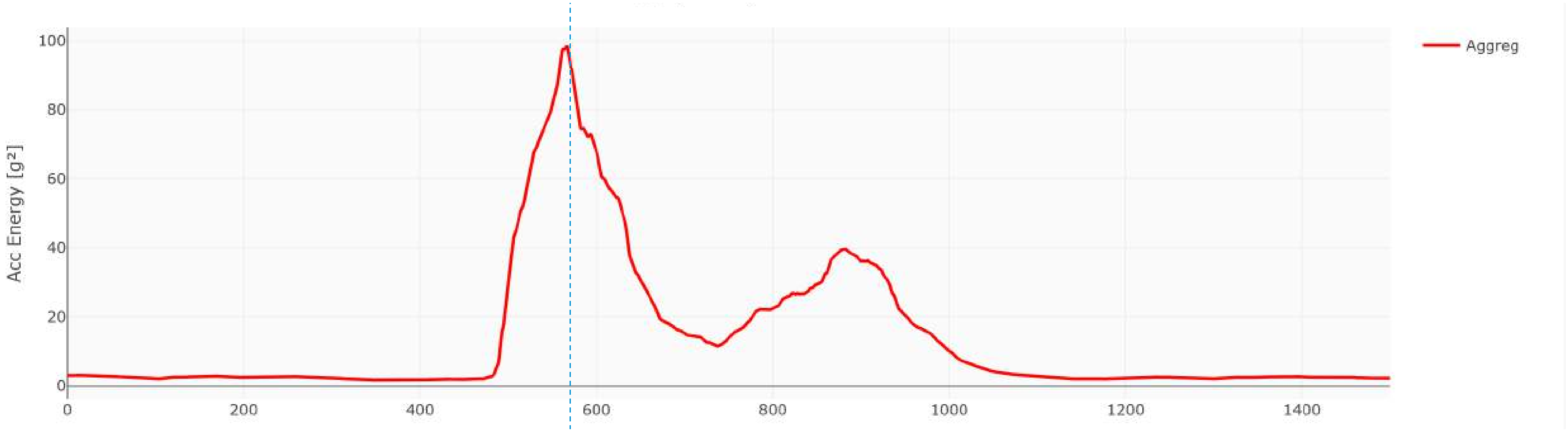
Acceleration Energy

$$E[n] = \sum_{m=n}^{n+M-1} a[m]^2$$

Energy calculation for each wheel



AGGREGATED SIGNAL

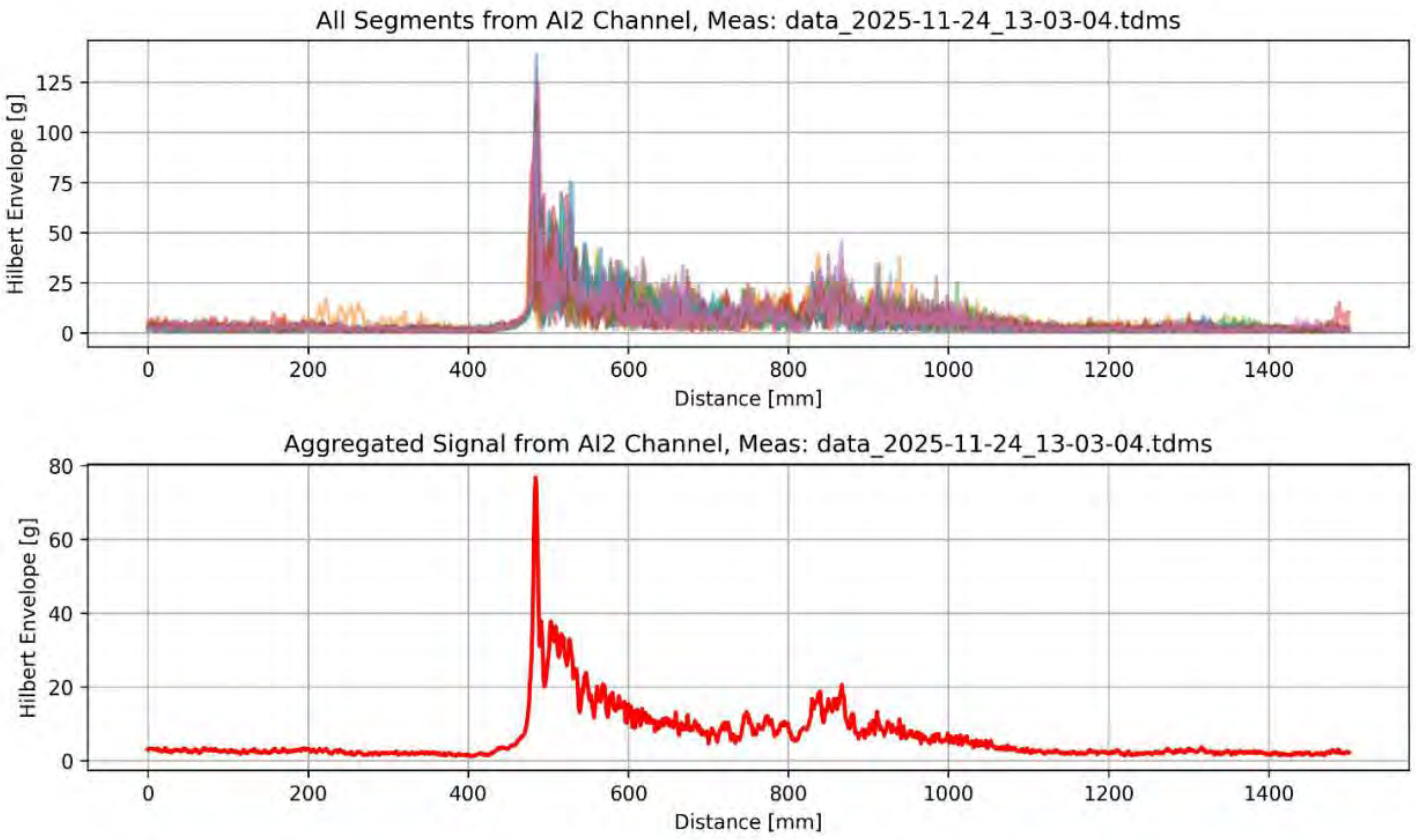


Distance (mm)

Energy is far more sensitive to detection of impacts

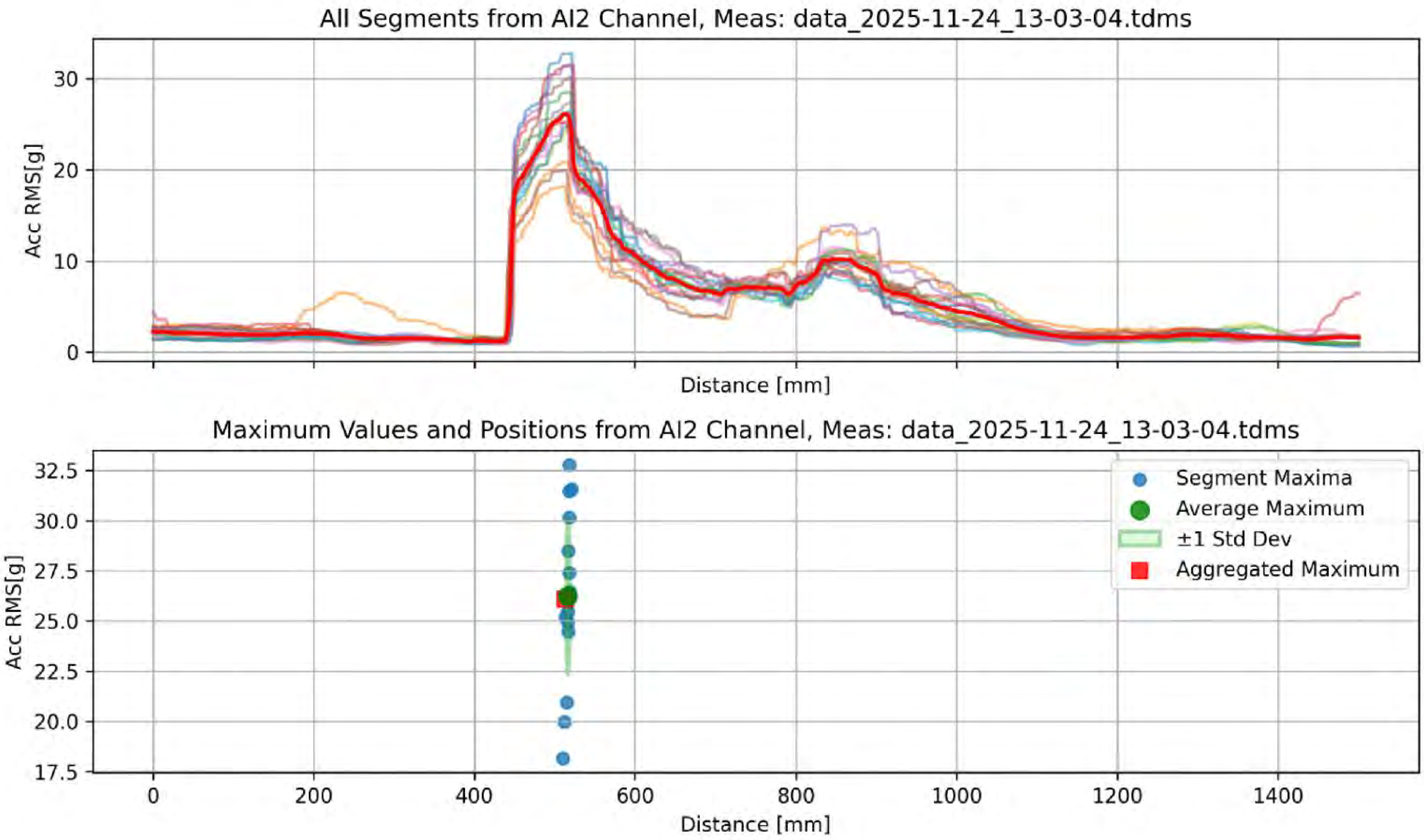
Acceleration signal: Hilbert envelope aggregation

$$e(t) = |\mathcal{H}\{x(t)\}|$$



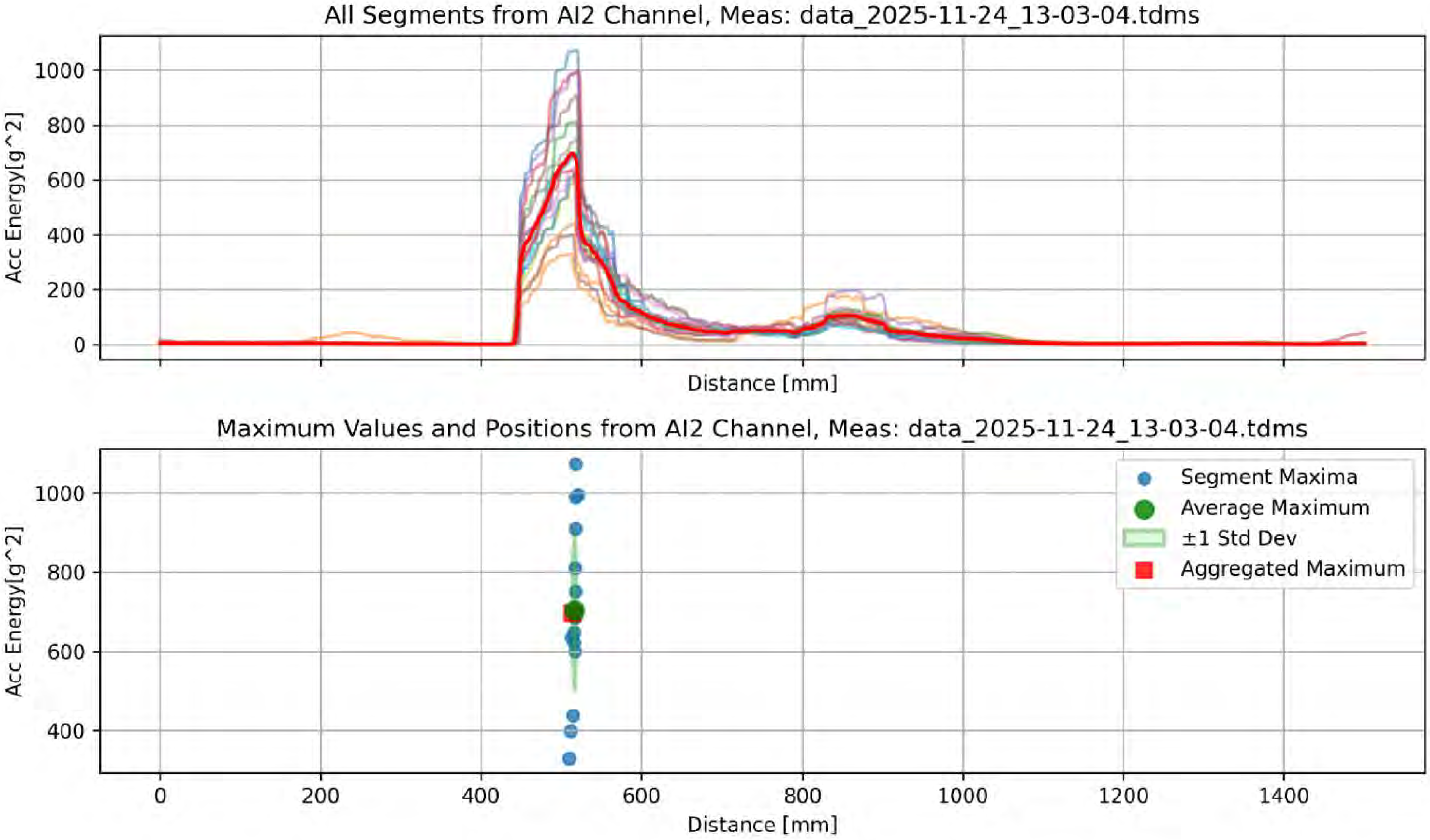
Spatial distribution of the P1 impact location

RMS



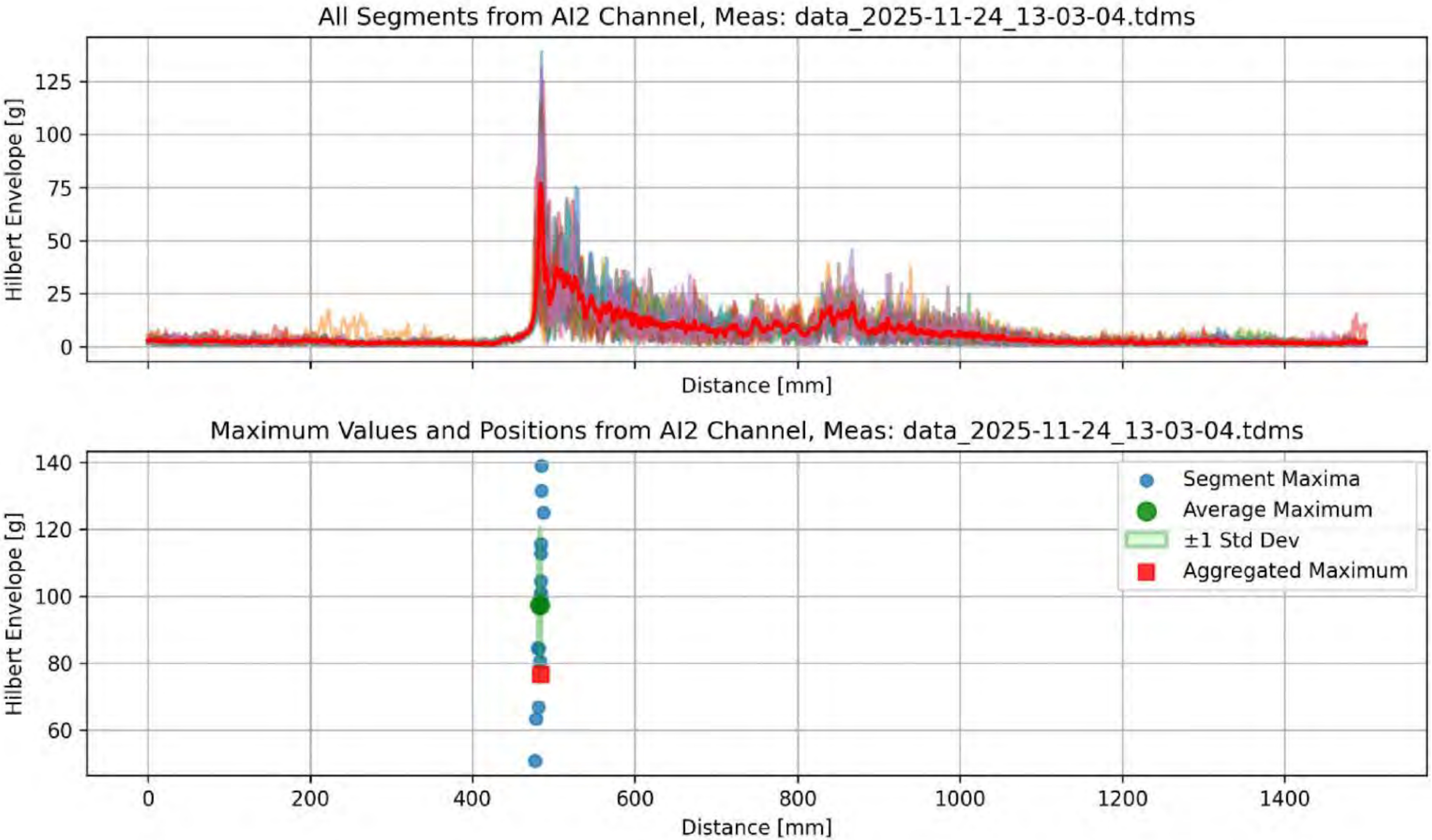
Spatial distribution of the P1 impact location

Energy

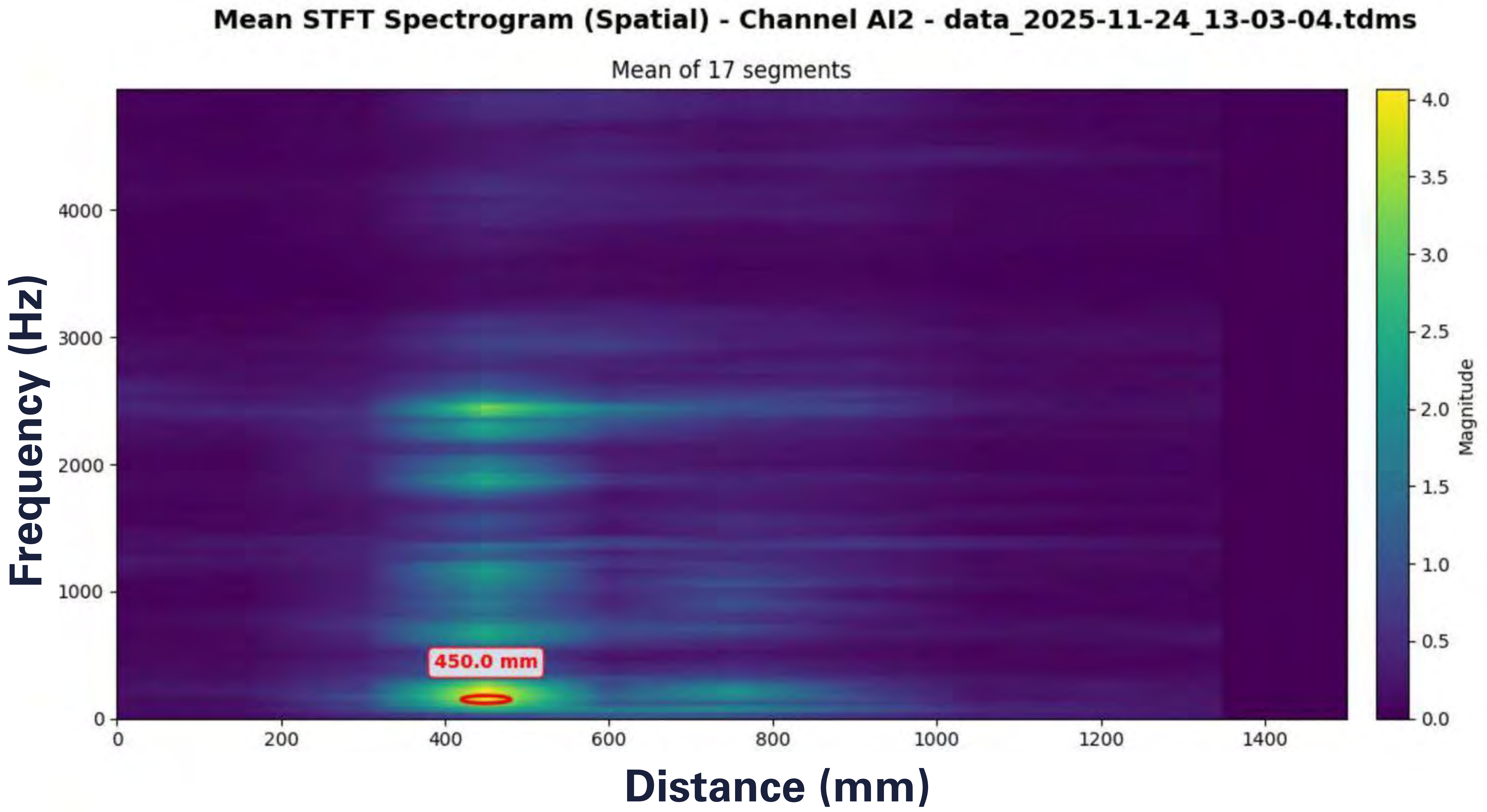


Spatial distribution of the P1 impact location

Hilbert envelope



Aggregated spatial spectrogram



Conclusion

- **High-Resolution Data Acquisition**: The system reliably captured vibration data from passing trains, with a sampling rate of 51,200 Hz, enabling detailed temporal and spectral analysis
- **Effective Impact Localization**: By combining inductive wheel sensors and accelerometer blocks, the system accurately mapped impact events to specific spatial locations on the crossing nose rail.
- **Feature Extraction: Temporal features (RMS, energy, Hilbert envelope)** and spectral features (FFT, PSD, STFT) were successfully extracted and analyzed, revealing consistent patterns in impact dynamics and dominant frequency components.